Dedicated EIC detector design/ Semi-inclusive DIS

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Brookhaven/RBRC Summer Program on Nucleon Spin Physics

Overview

- Physics goals in semi-inclusive DIS:
  - Helicity structure.
  - Transverse spin structure.
- Accelerator design.
- Interaction point layout.
- **How these guide EIC detector design.**
- **Current design ideas.**

Physics goals

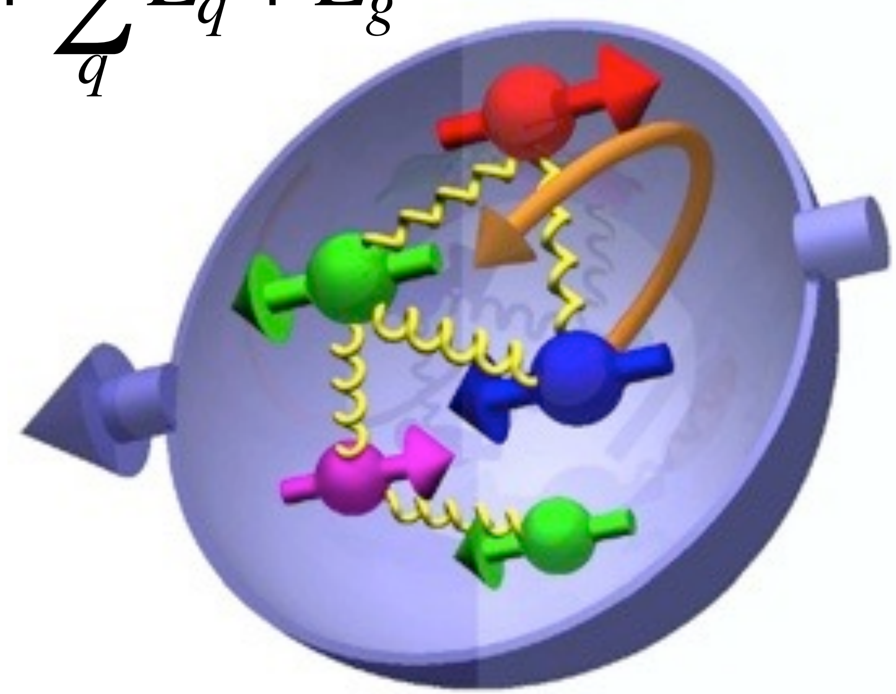
A brief summary of SIDIS measurements

Spin of the nucleon

- Disentangle q, g and orbital contributions

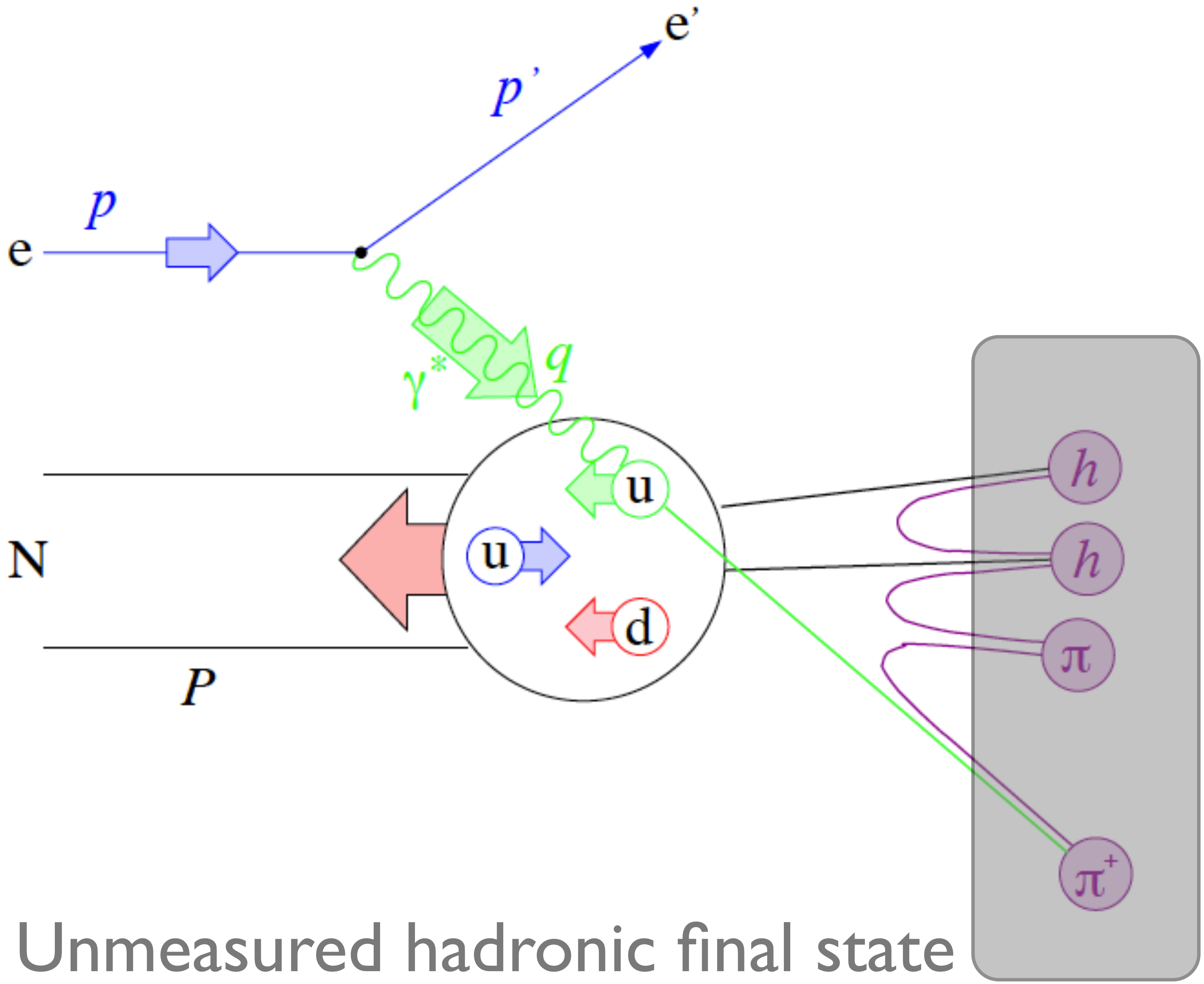
$$\frac{1}{2}\hbar = \left\langle P,\frac{1}{2} \mid J^z_{QCD} \mid P,\frac{1}{2}\right\rangle = \sum_q \frac{1}{2} S^z_q + S^z_g + \sum_q L^z_q + L^z_g$$

- Spin-dependent parton dynamics
  - Sivers, Boer-Mulders
- Spin-dependent fragmentation.



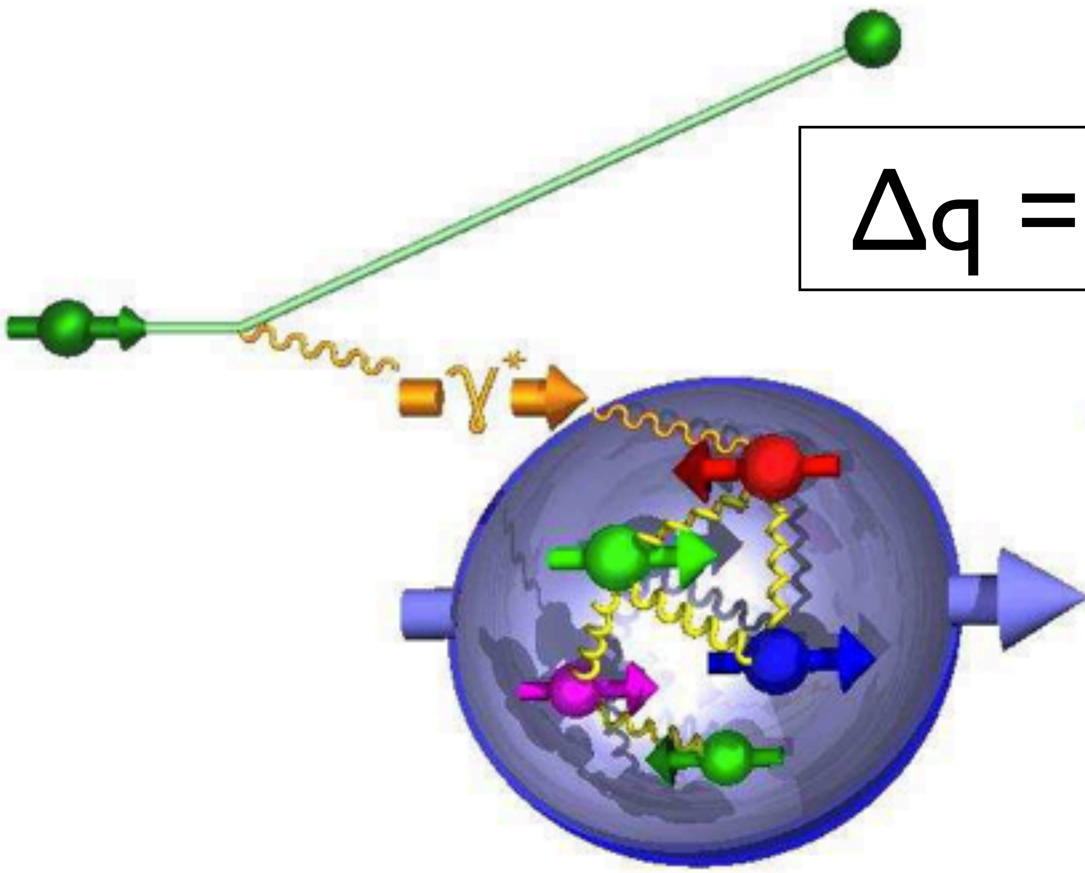
▷ **Many quantities are still poorly known.**

Inclusive DIS



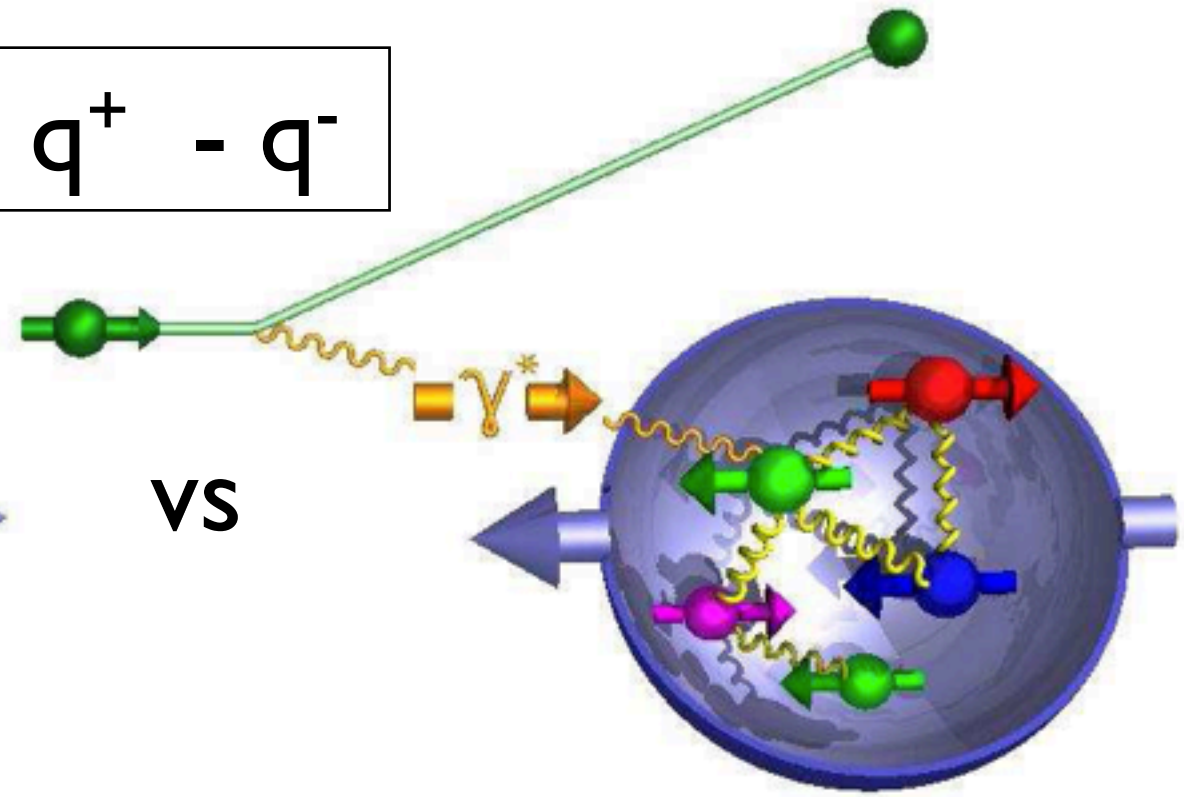
Unmeasured hadronic final state

Longitudinal spin in DIS



$\Delta q = q^{+} - q^{-}$

vs



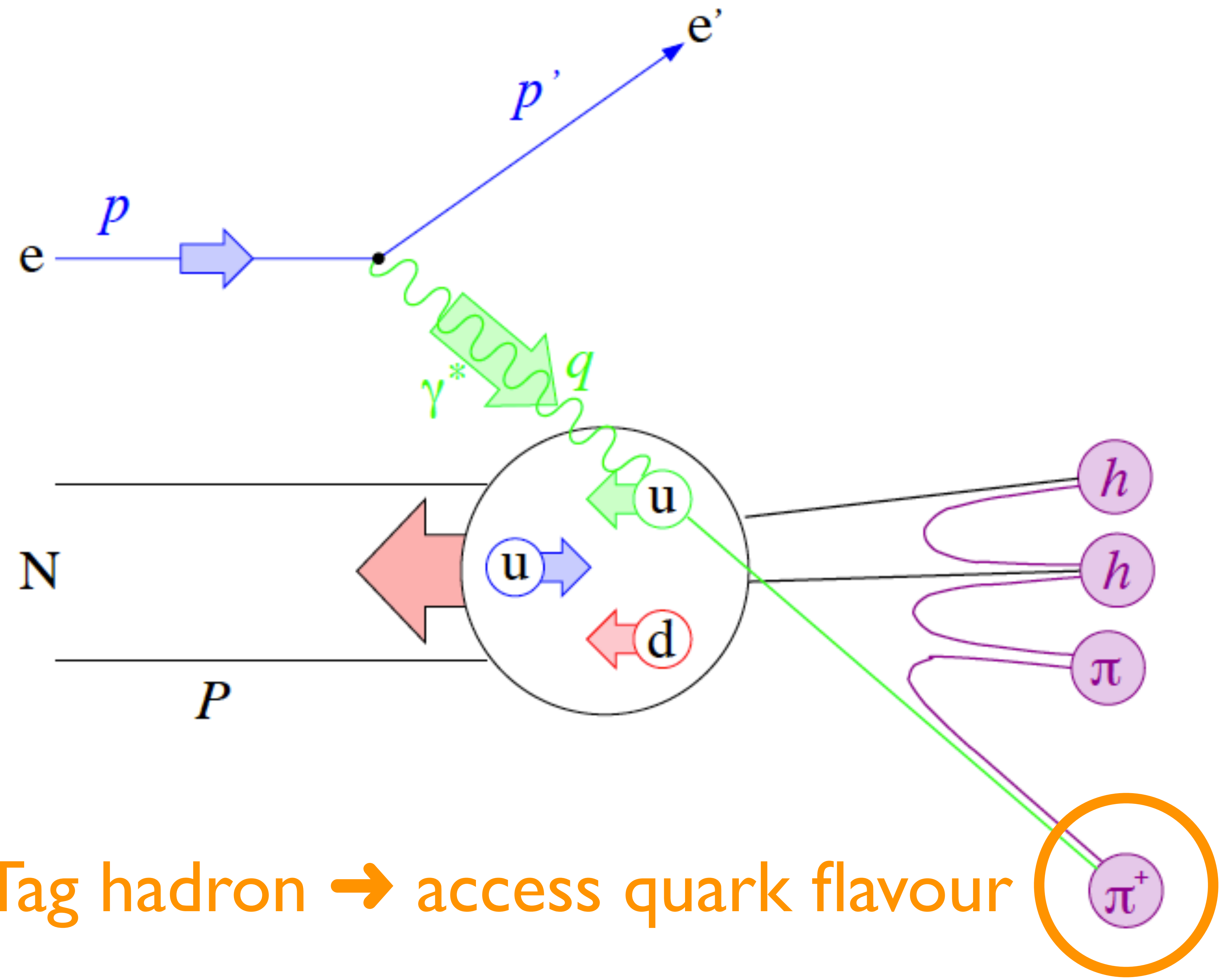
Quark (spin ½)
absorbs
photon (spin 1)
and flips helicity

$F_1(x) = \Sigma_q\, q^{+}(x) + q^{-}(x)$

$g_1(x) = \Sigma_q\, q^{+}(x) - q^{-}(x)$

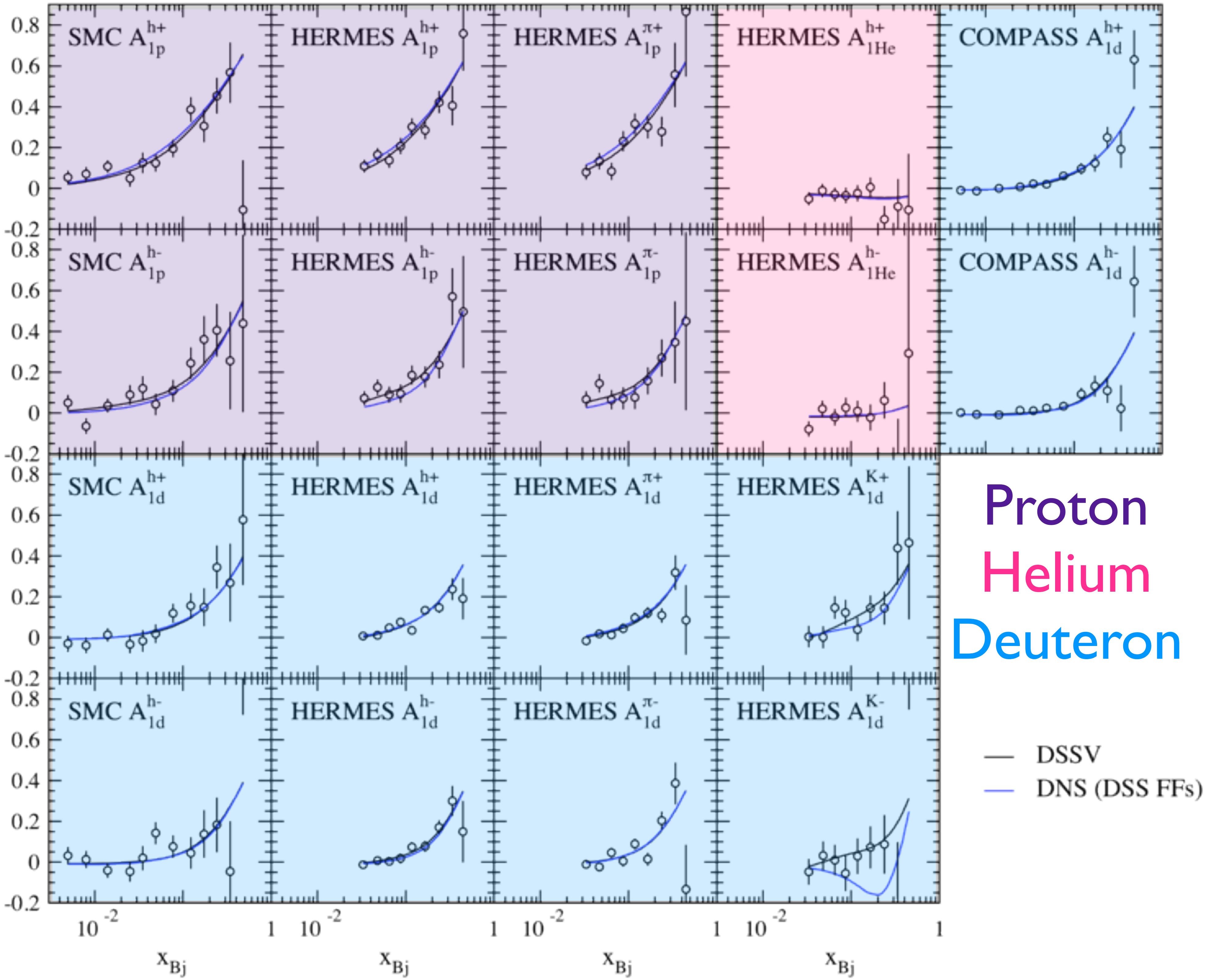
$A_1 = g_1 / F_1$

Semi-inclusive DIS: SIDIS



Tag hadron ➜ access quark flavour

Semi-inclusive DIS asymmetries

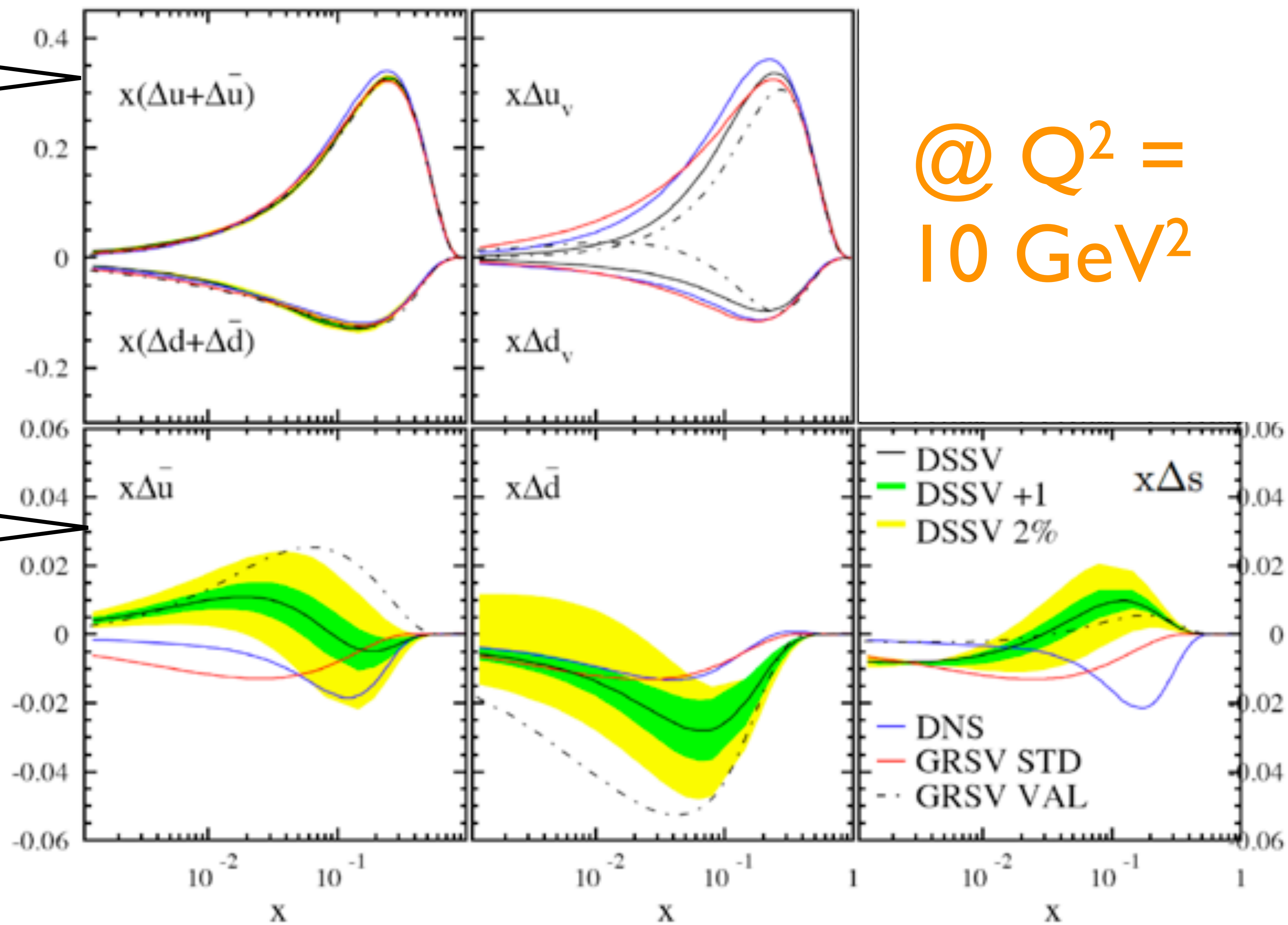


Flavour-dependence

$\Delta u = 0.813$
$\Delta d = -0.459$

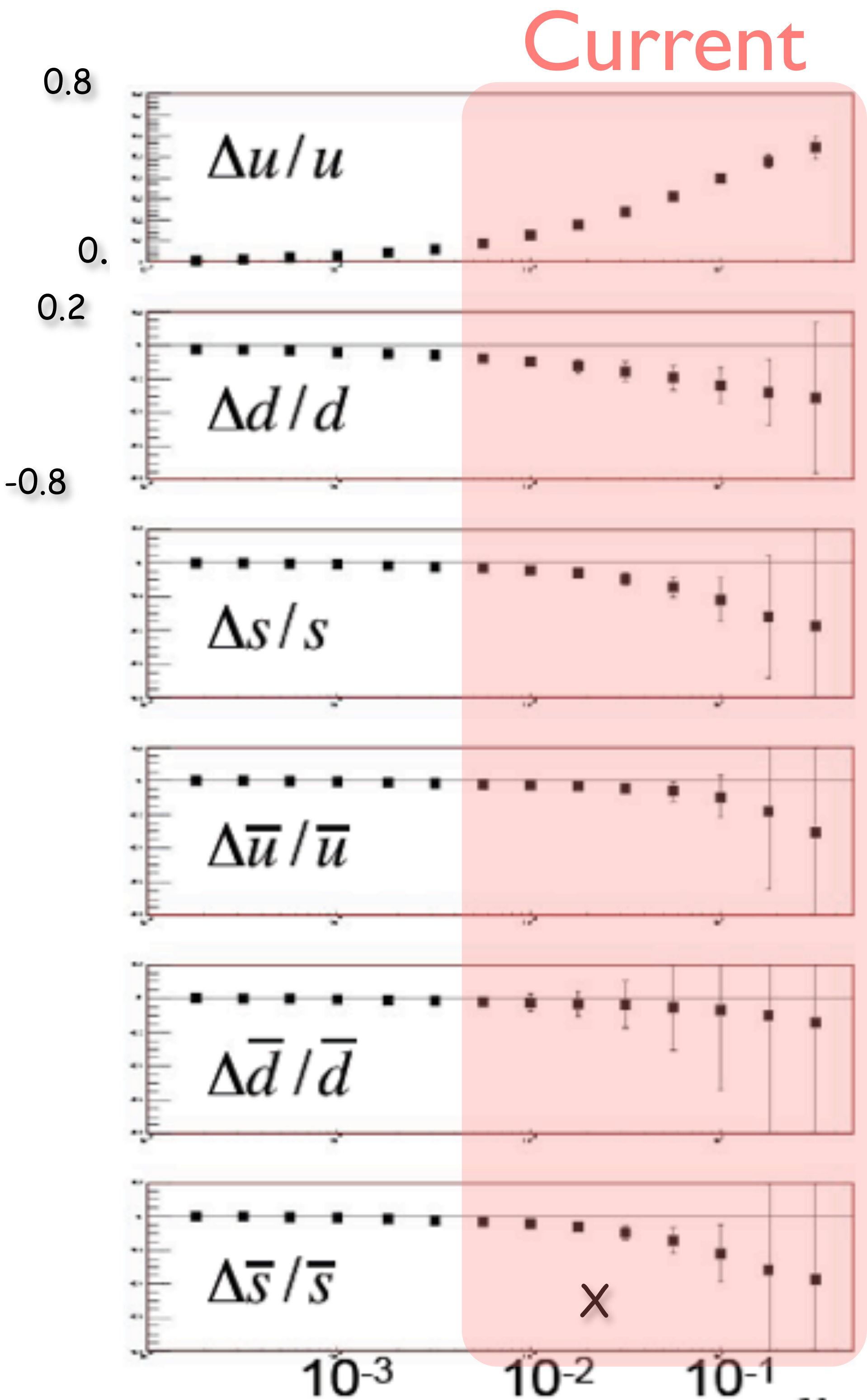
$\Delta \bar{u} = 0.036$
$\Delta \bar{d} = -0.115$
$\Delta \bar{s} = -0.057$

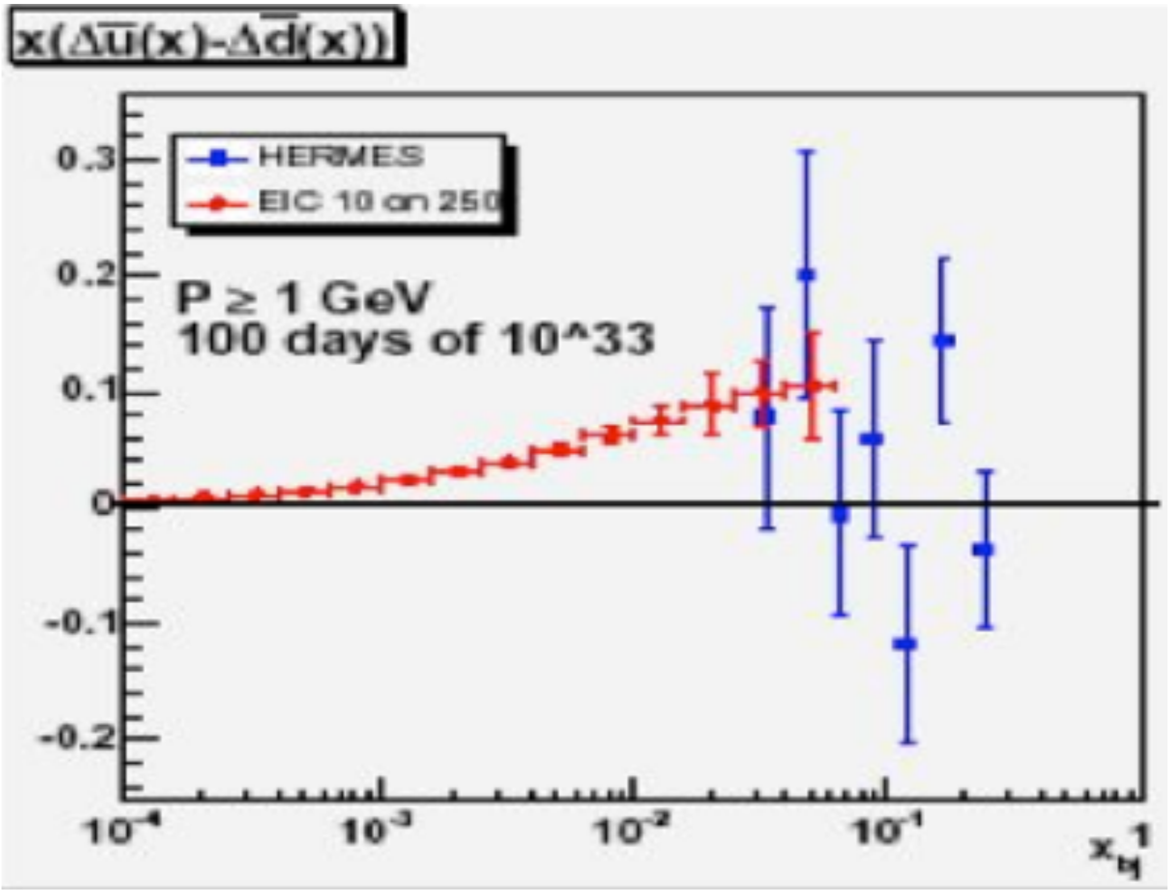
$\Delta\Sigma = 0.242$



@ $Q^2 = 10\ \mathrm{GeV}^2$

Flavour-dependence



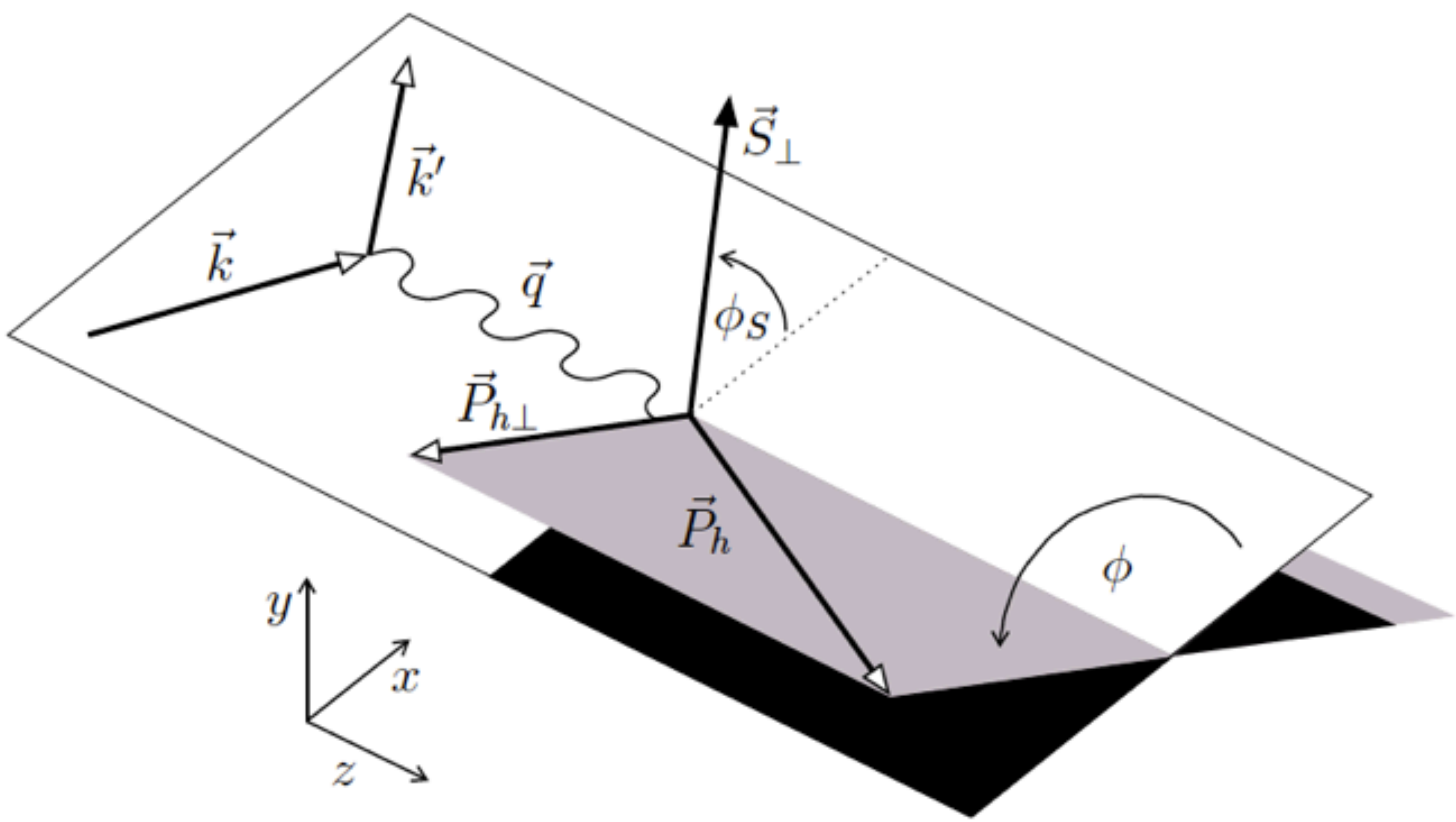


- 10 + 250 GeV
- $9fb^{-1}$

Transverse spin in SIDIS

- Collins & Sivers - different azimuthal dependence

➡ Disentangle the effects



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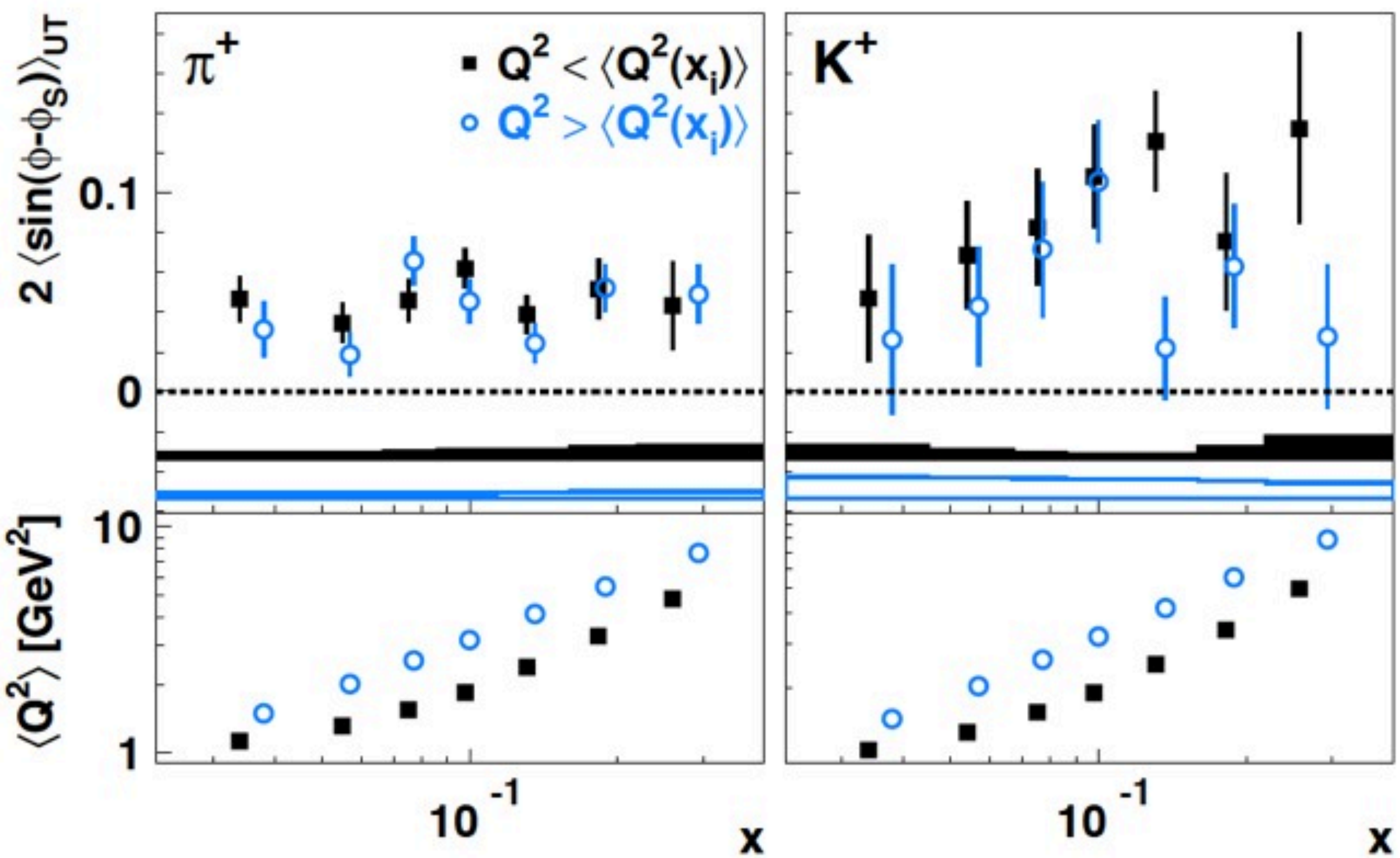
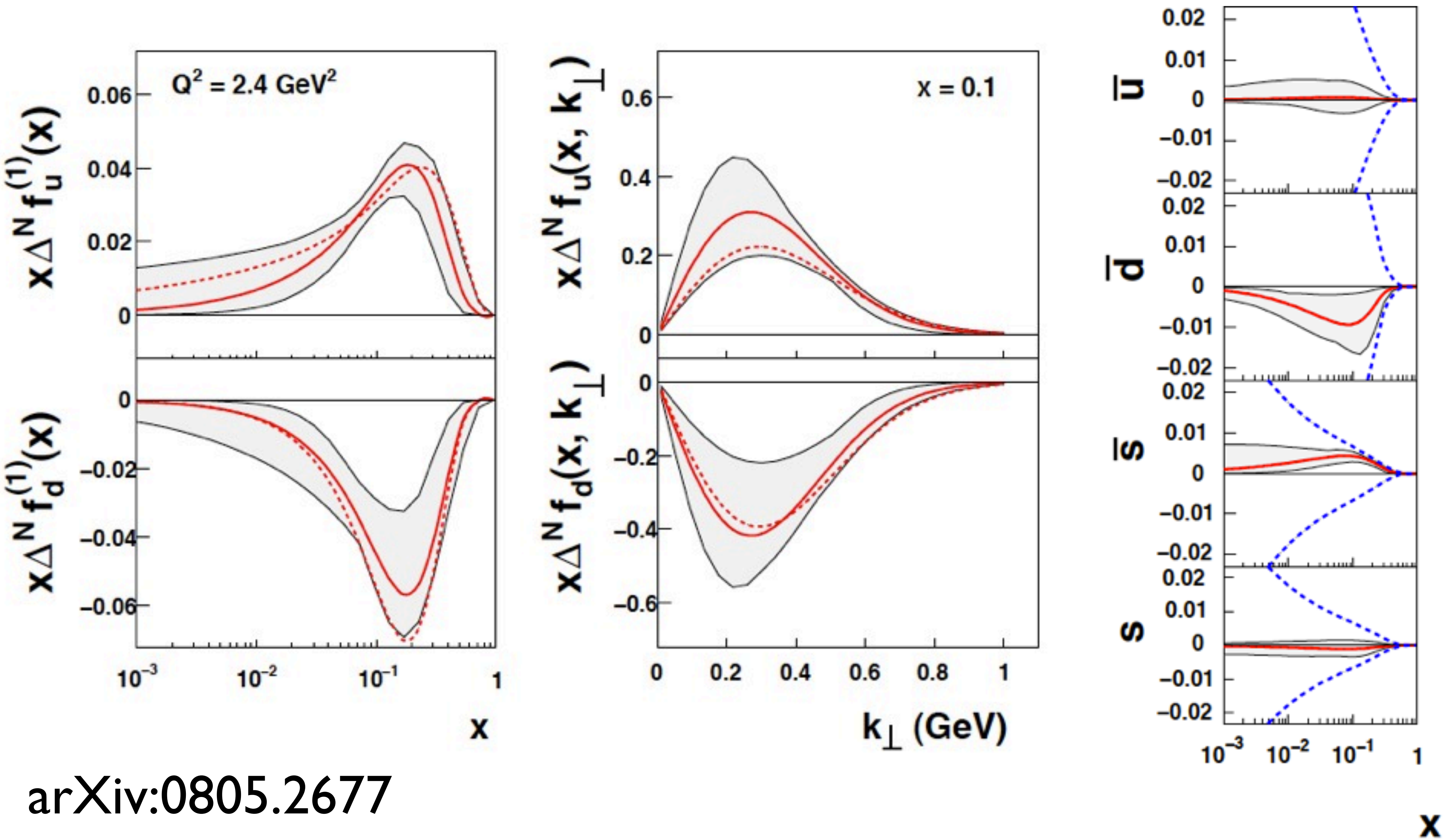


Phys. Rev. Lett. 103 (2009) 152002

Current status

Sivers functions



arXiv:0805.2677

Current status

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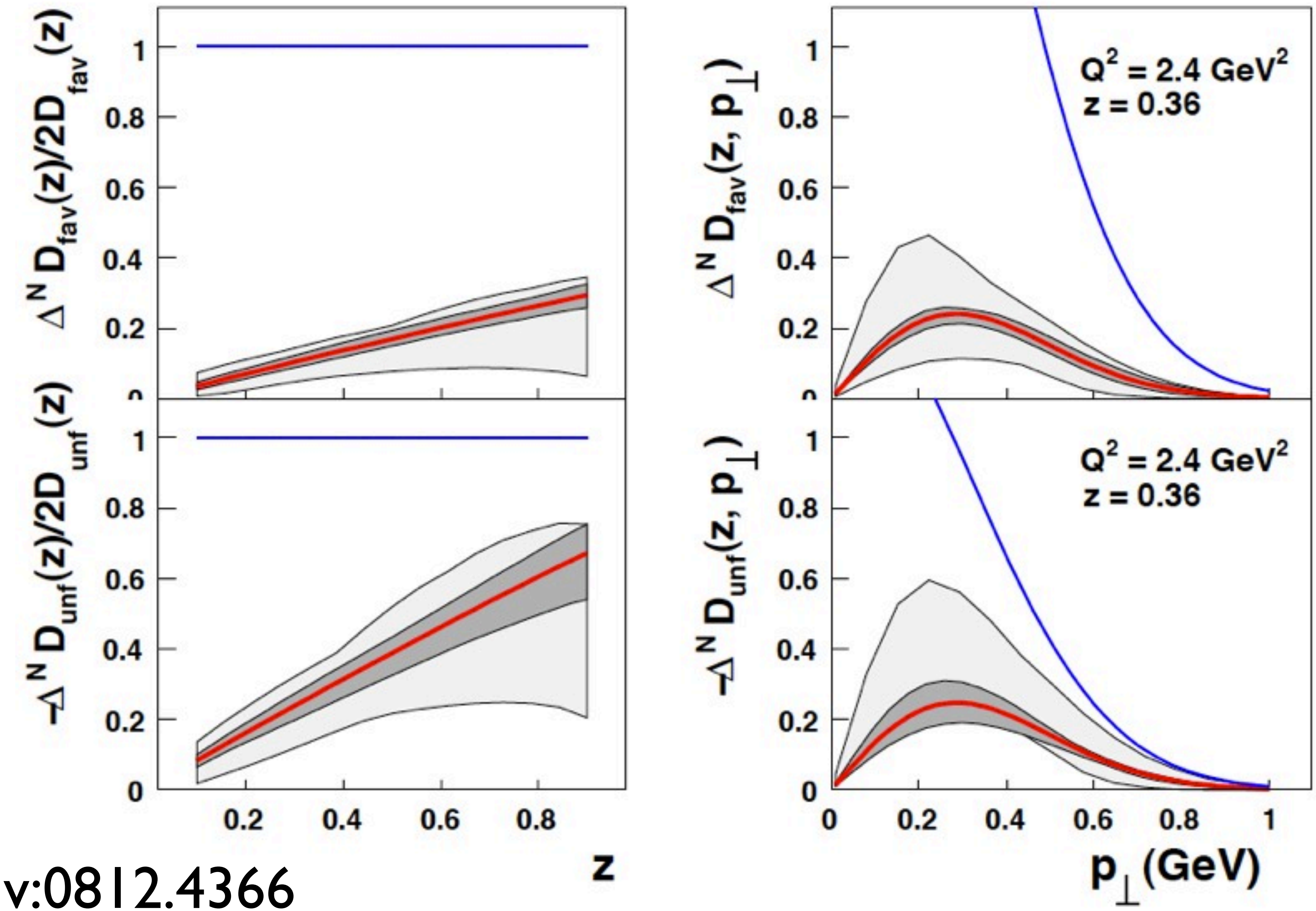
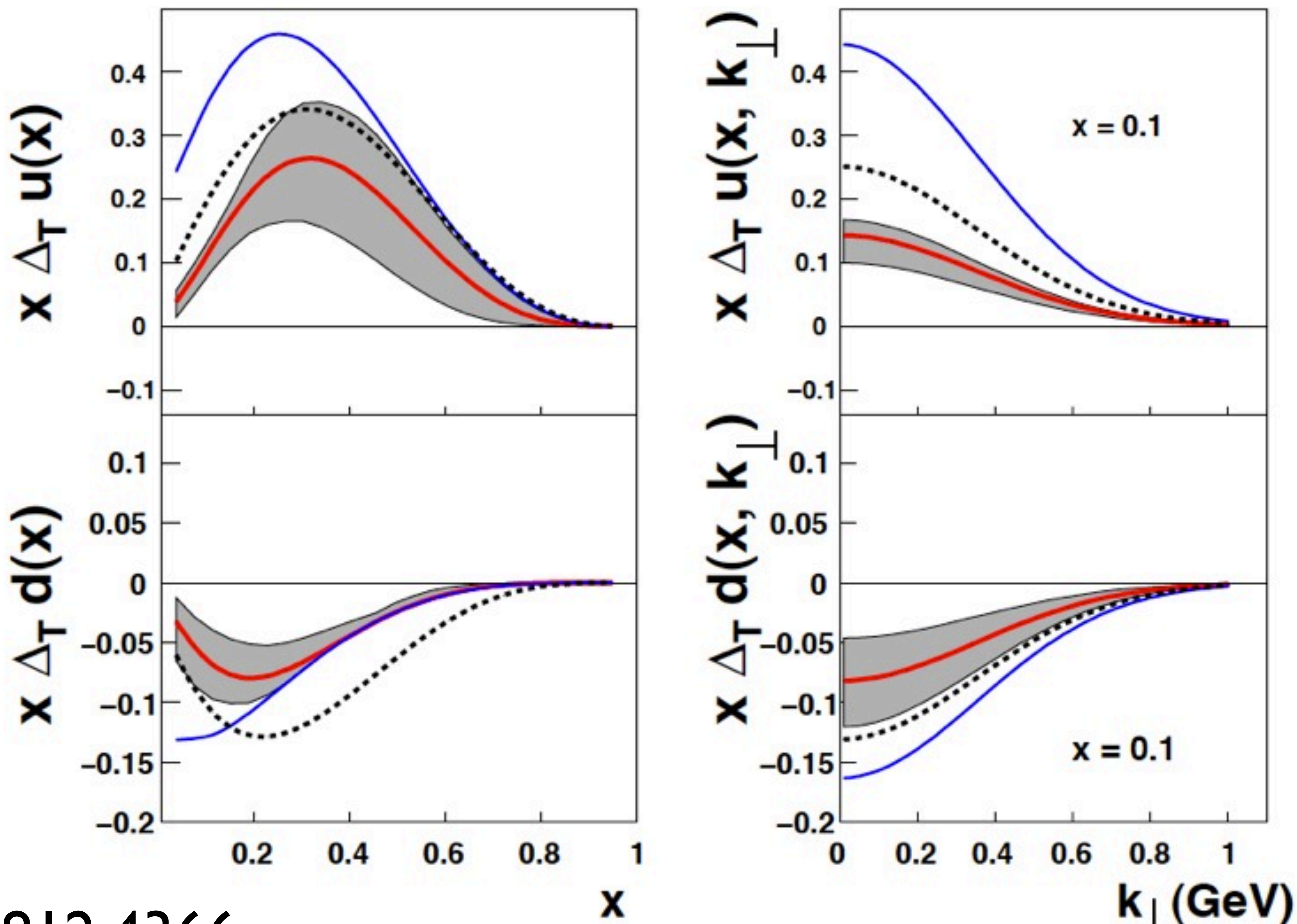


arXiv:0812.4366

Current status

Transversity



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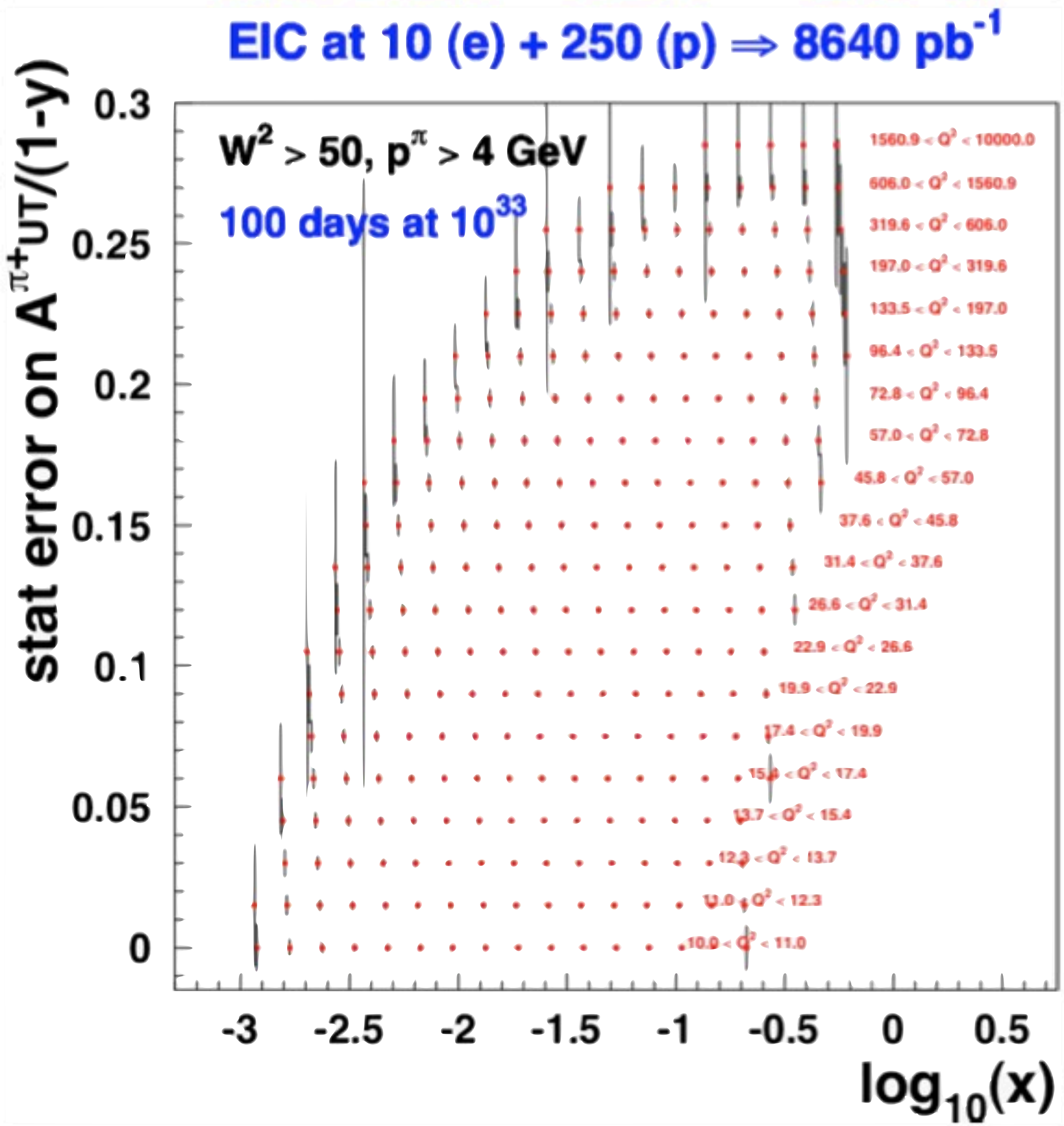
Sivers at EIC

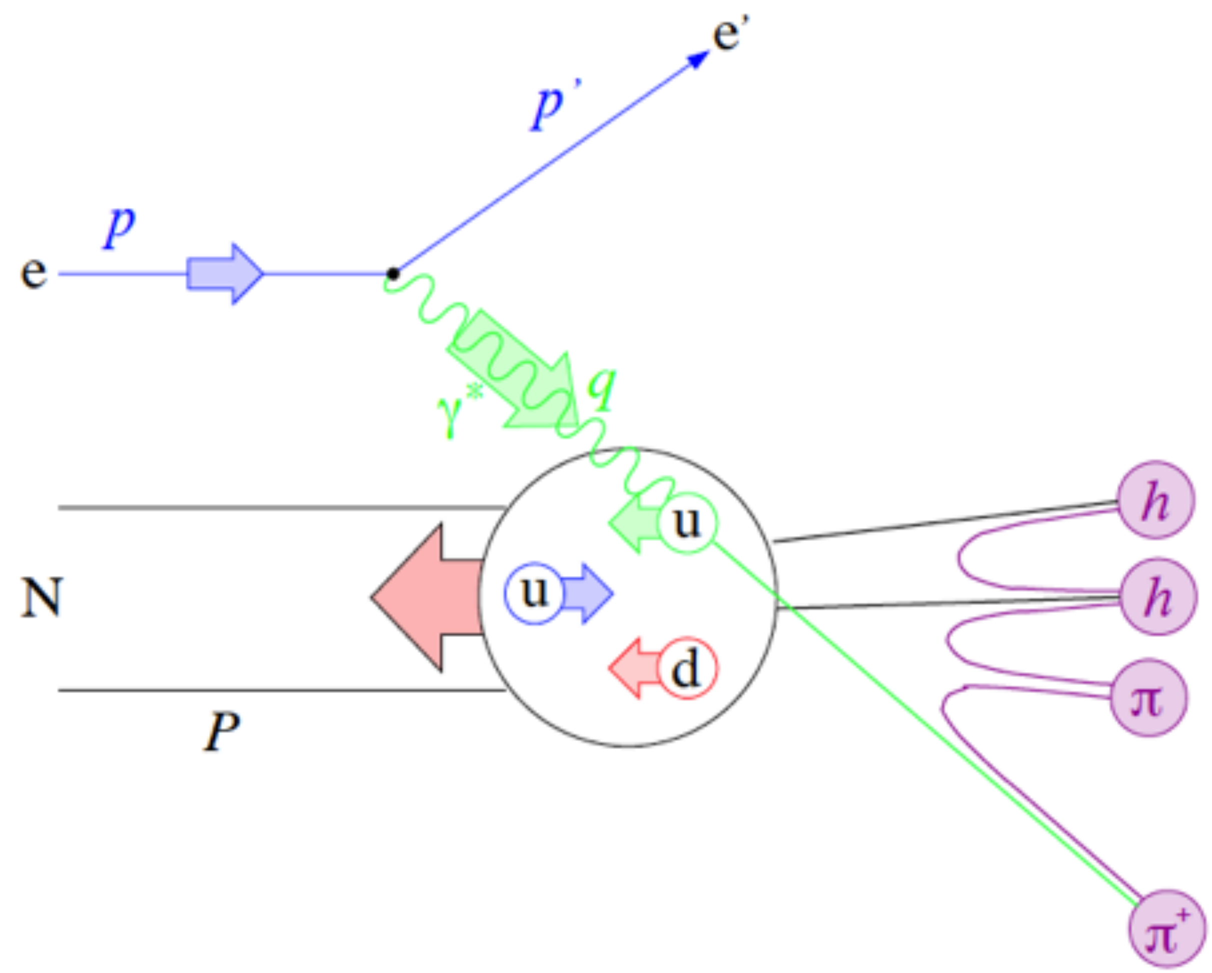
- High luminosity

➡ multi-dimensional binning: x, Q^2, z, p_T



Physics requirements

- ☑ (Semi-)inclusive & exclusive
- ☑ Hadron identification
- ☑ Q^2 'lever arm'
- ☑ Span in x
- ☑ Polarisation
- ☑ Luminosity



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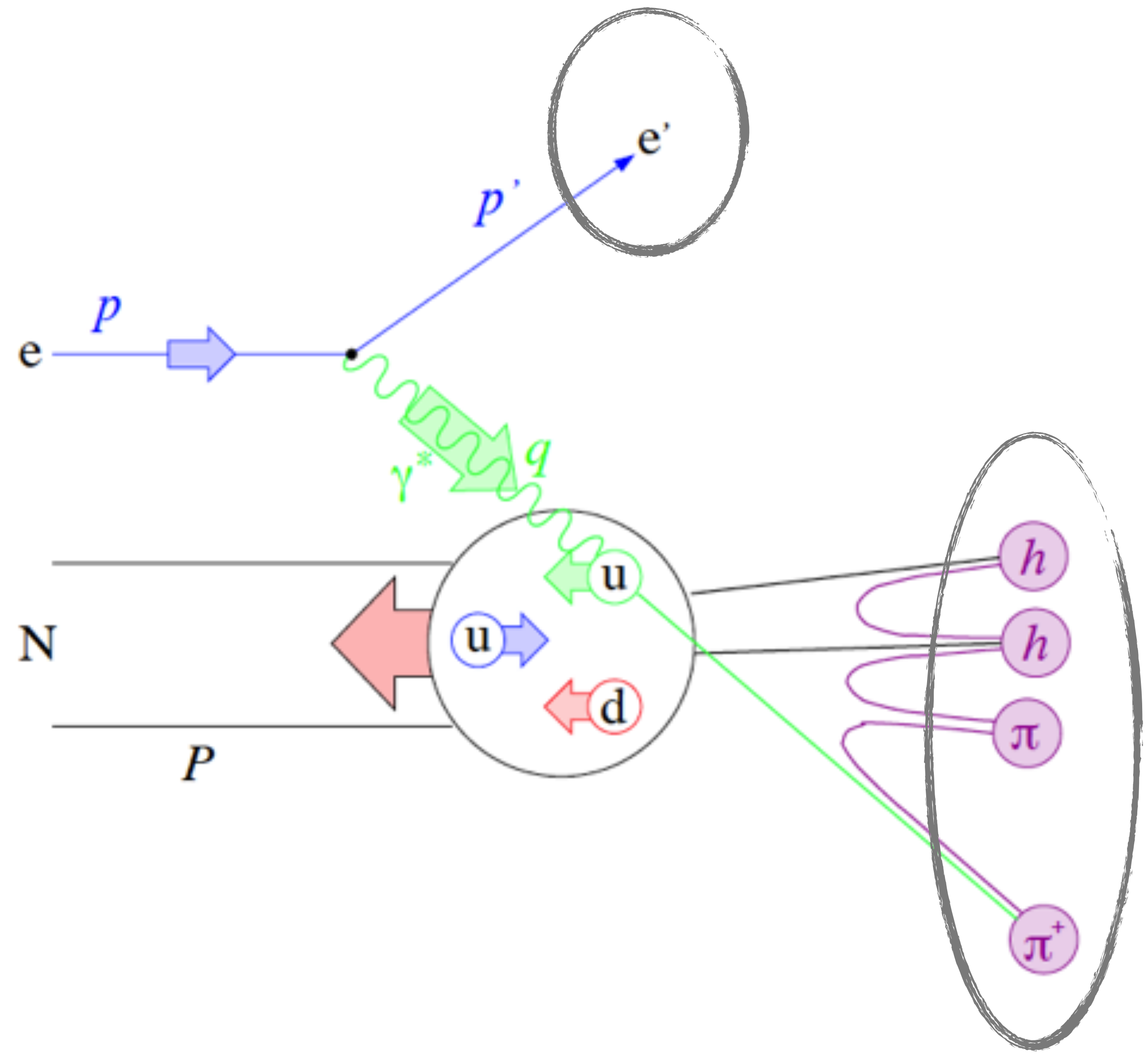

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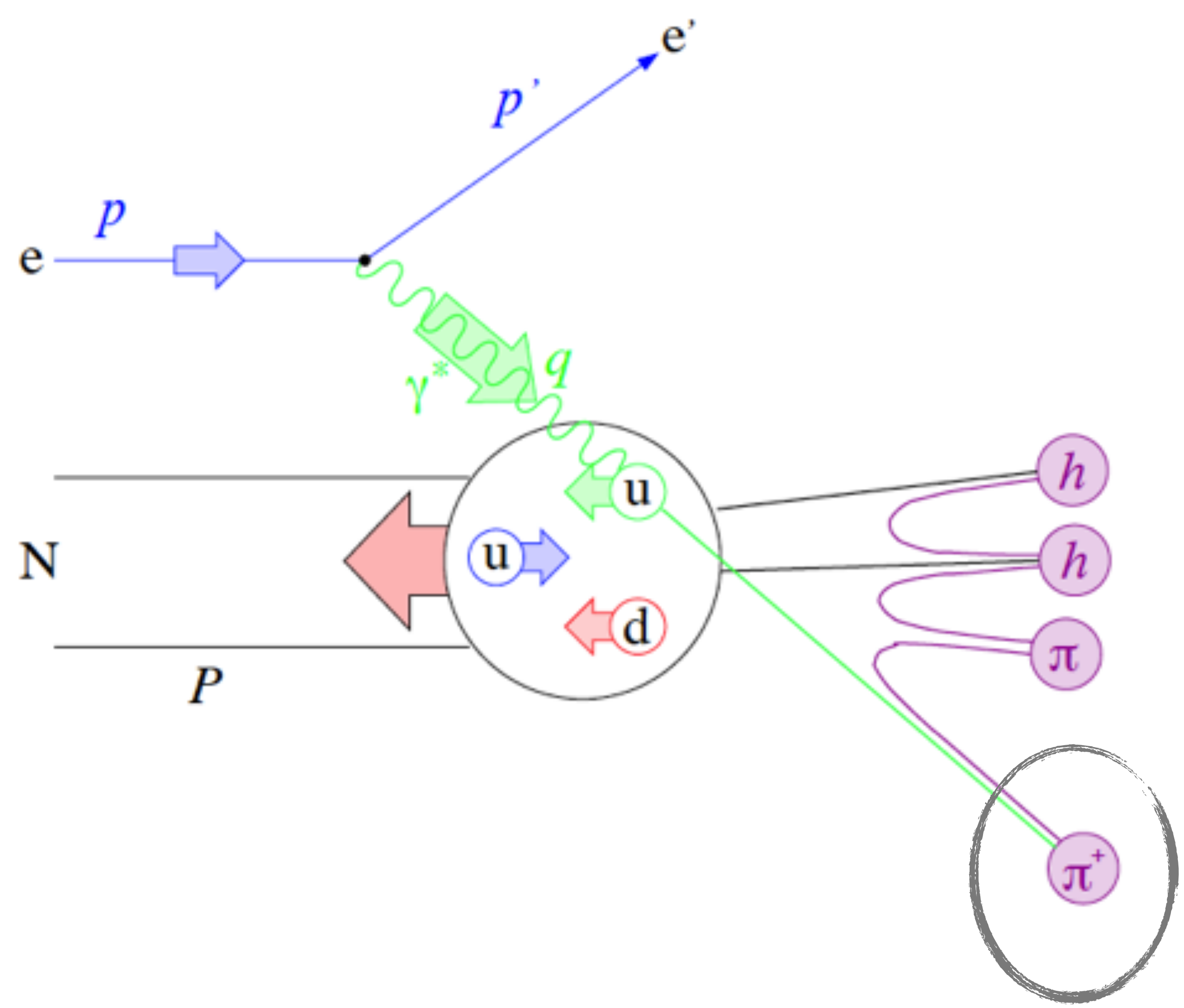

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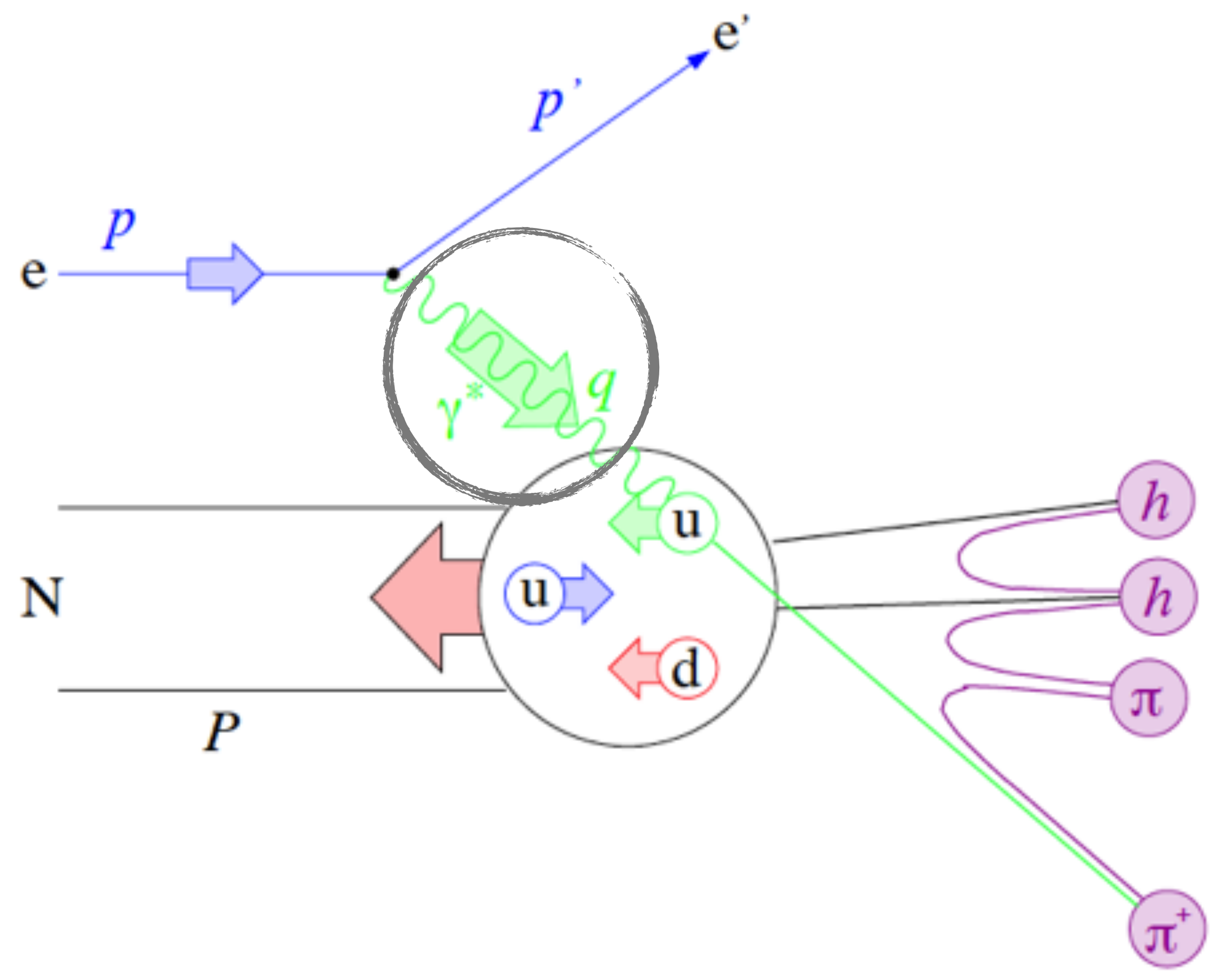


Required measurements

What must we measure to achieve our physics goals?

Energy:

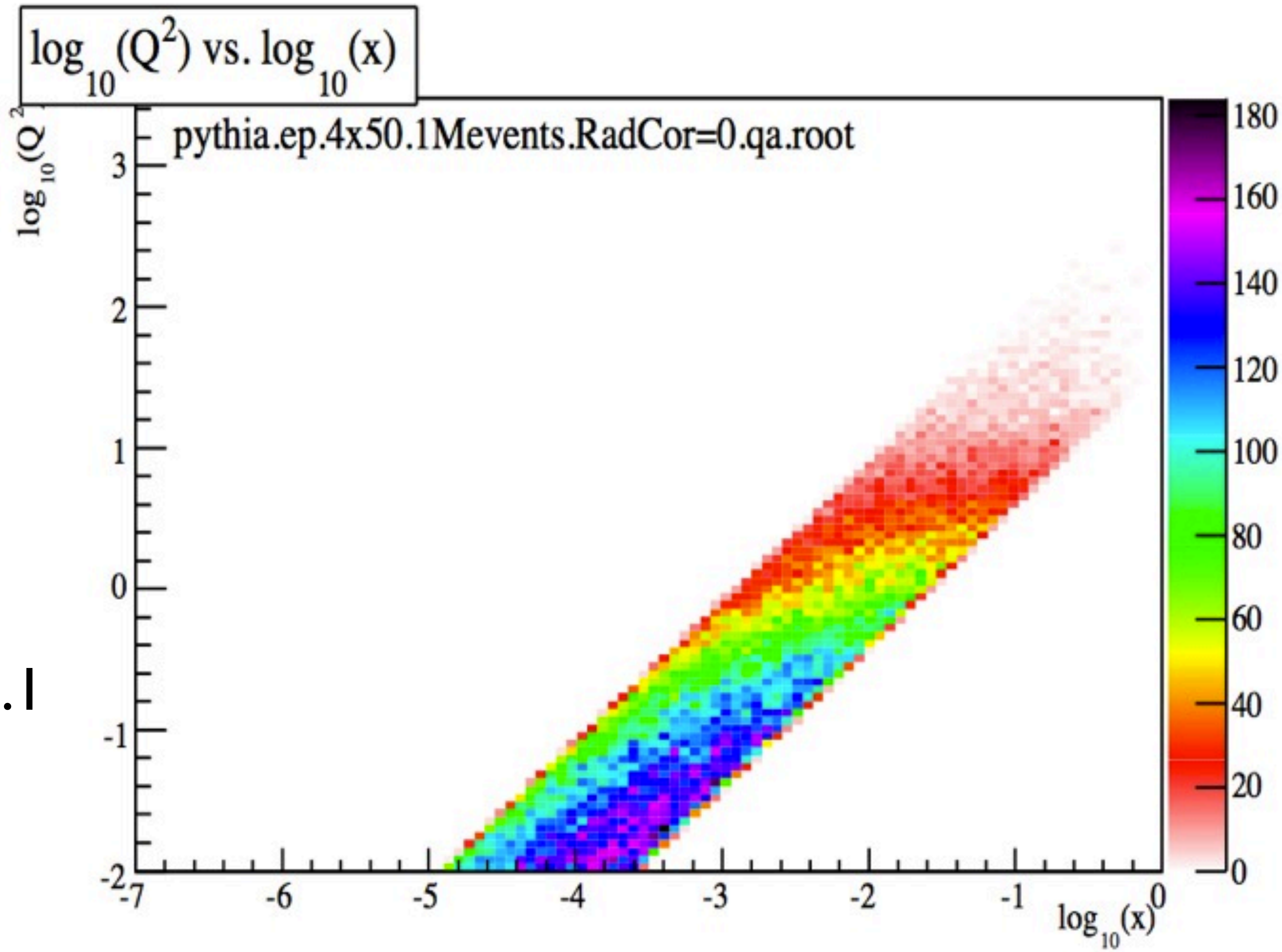
e 5-30 GeV,

p 50-250(325) GeV

Au 100(130) GeV.

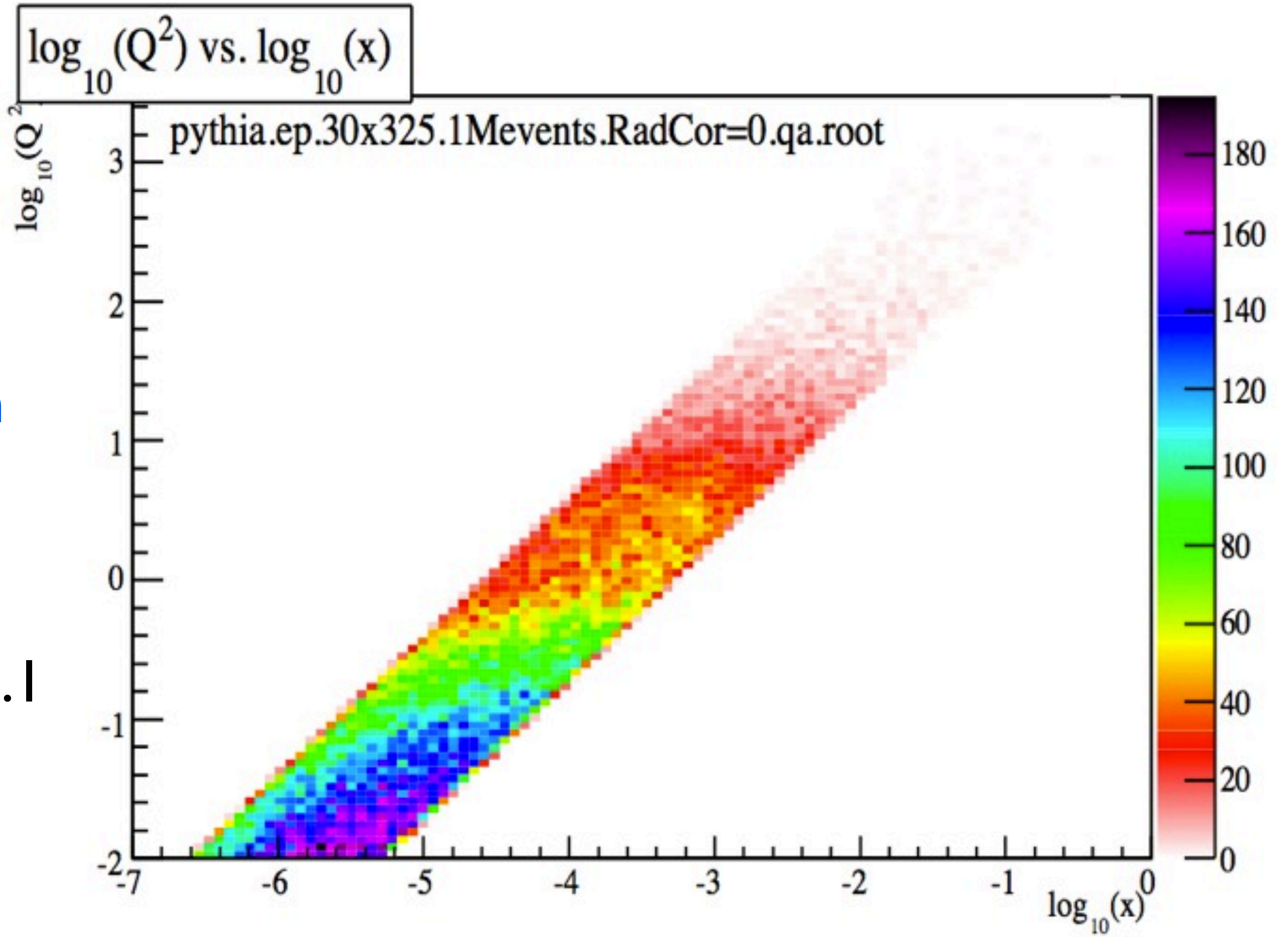
x and Q^2

- PYTHIA
- 4 GeV electron
- 50 GeV proton
- $x \sim 10^{-3}$ @ Q^2 0.1



x and Q^2

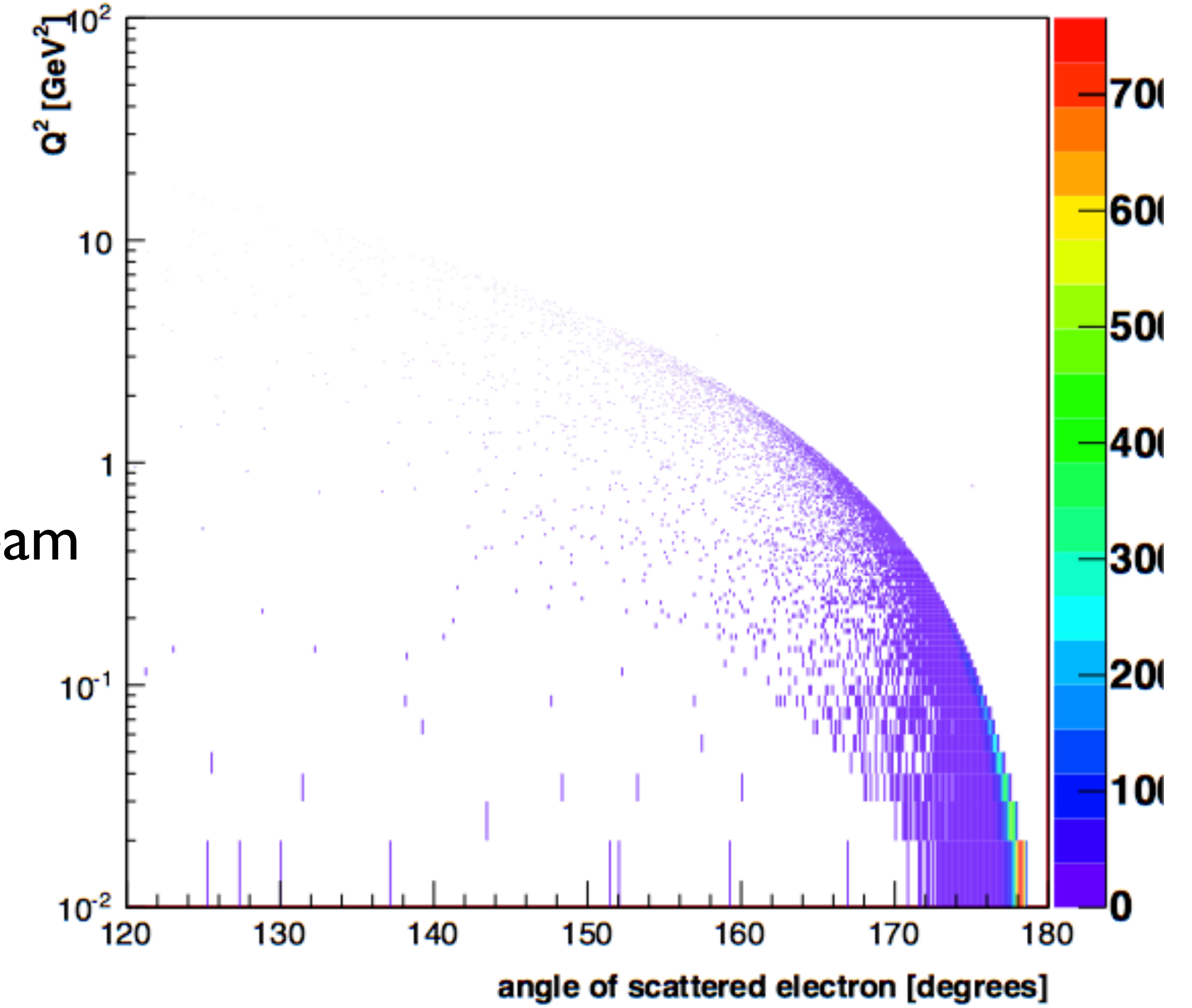
- PYTHIA
- 30 GeV electron
- 325 GeV proton
- $x \sim 10^{-5}$ @ Q^2 0.1



Q^2 reach : electron detection

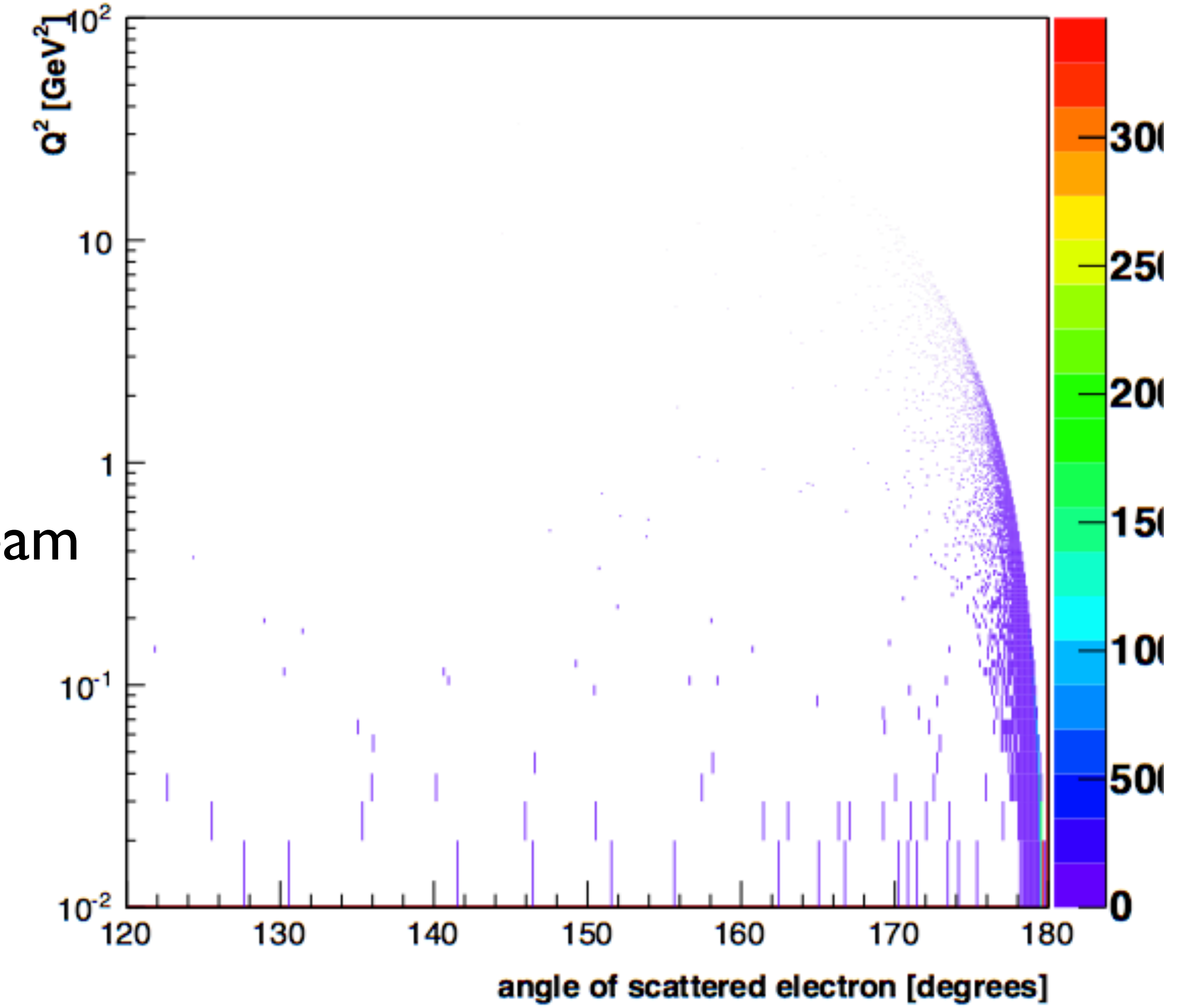
- Independent of hadron beam energy
- **4 GeV** electron

▸ Electrons up to **~2°**



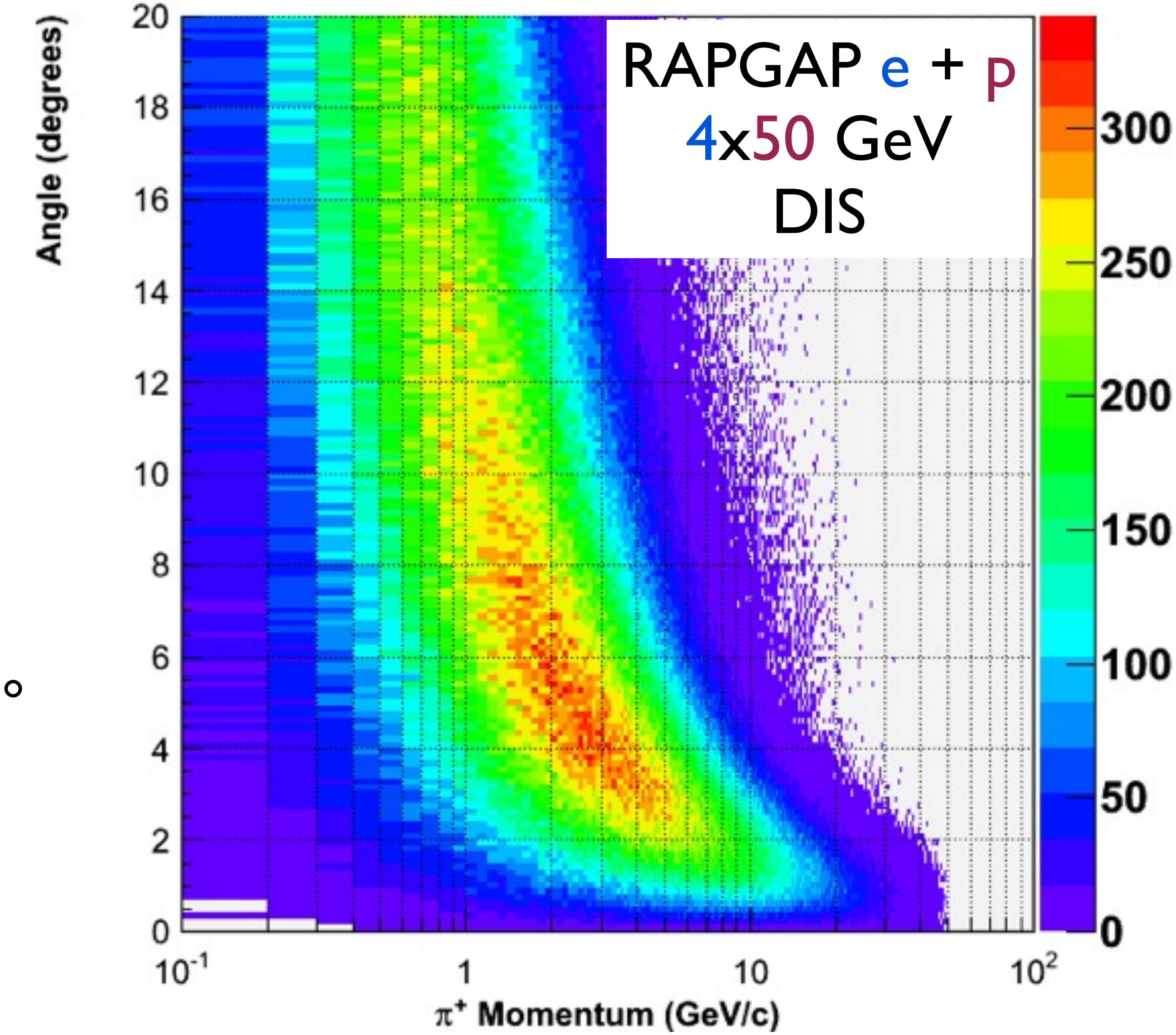
Q^2 reach : electron detection

- Independent of hadron beam energy
- **20 GeV** electron
- Electrons at **<1°**



Hadron detection: DIS

- **Strongly** dependent on hadron beam energy:
  - **50 GeV:** π at several °
  - **250 GeV:** π **< 4°**
- **High** momentum



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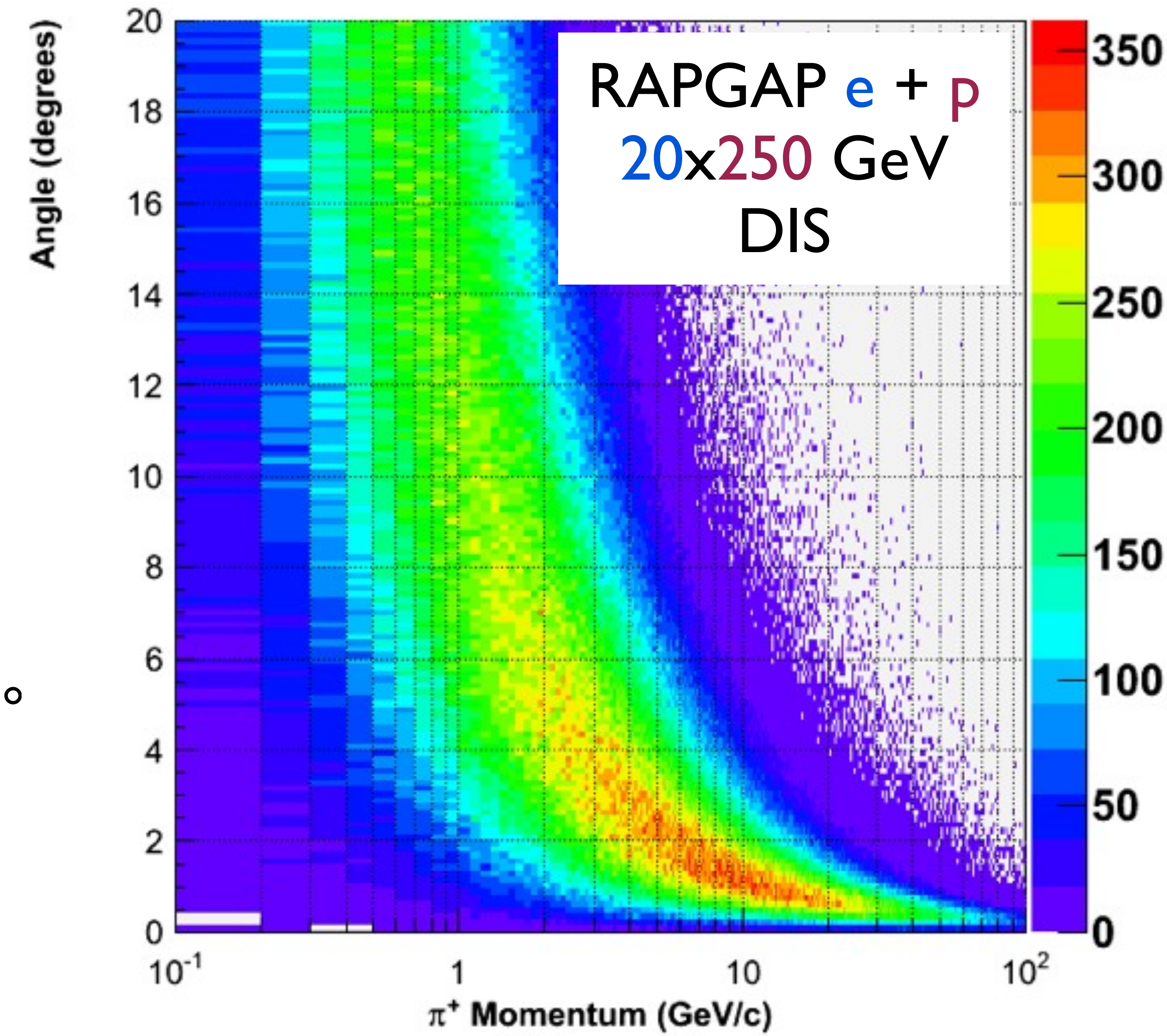
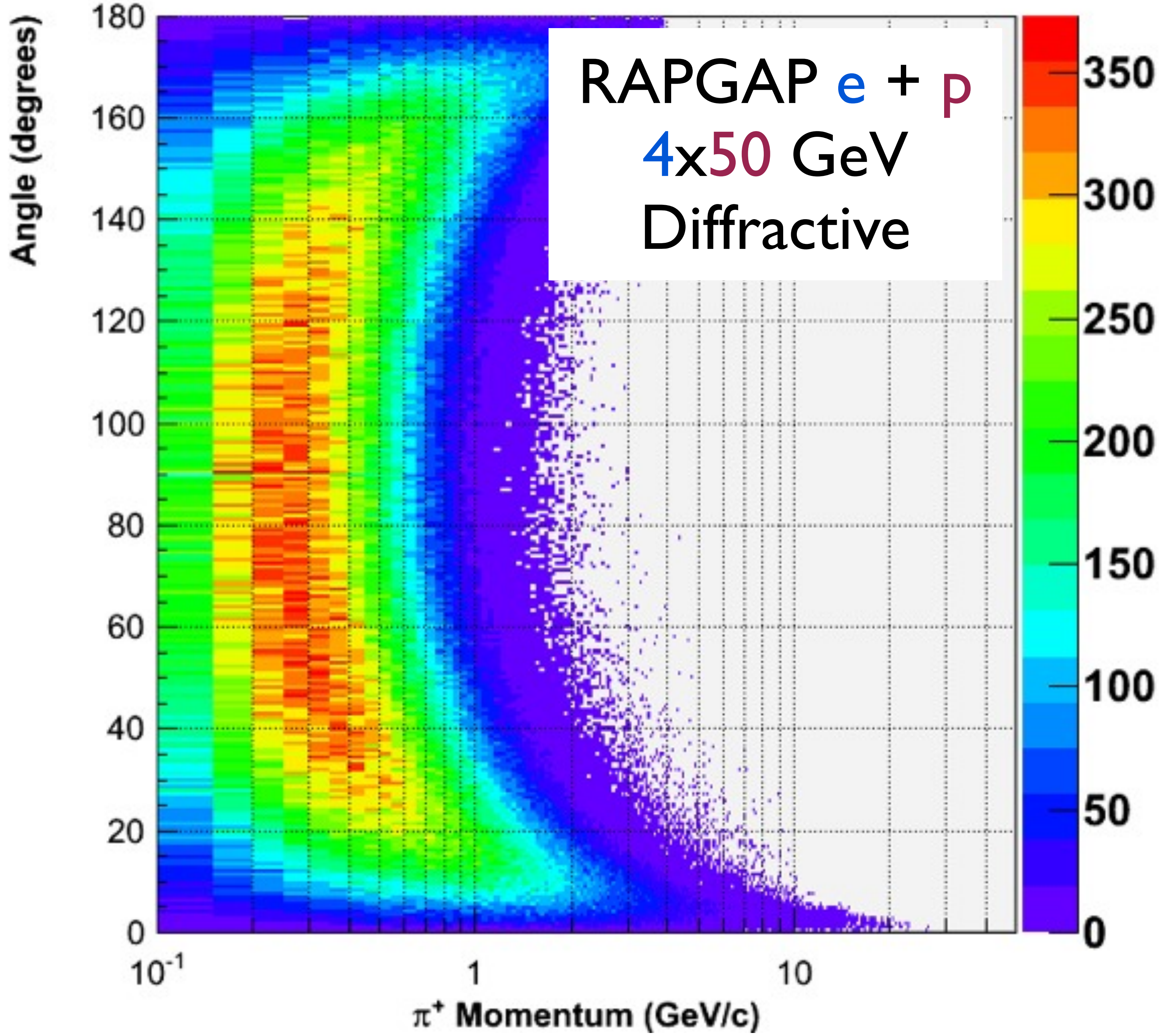


Hadron detection: diffractive

- **Little** energy-dependence
- Easy-to-detect angles
- Very **wide** angular range
- **Low** momentum



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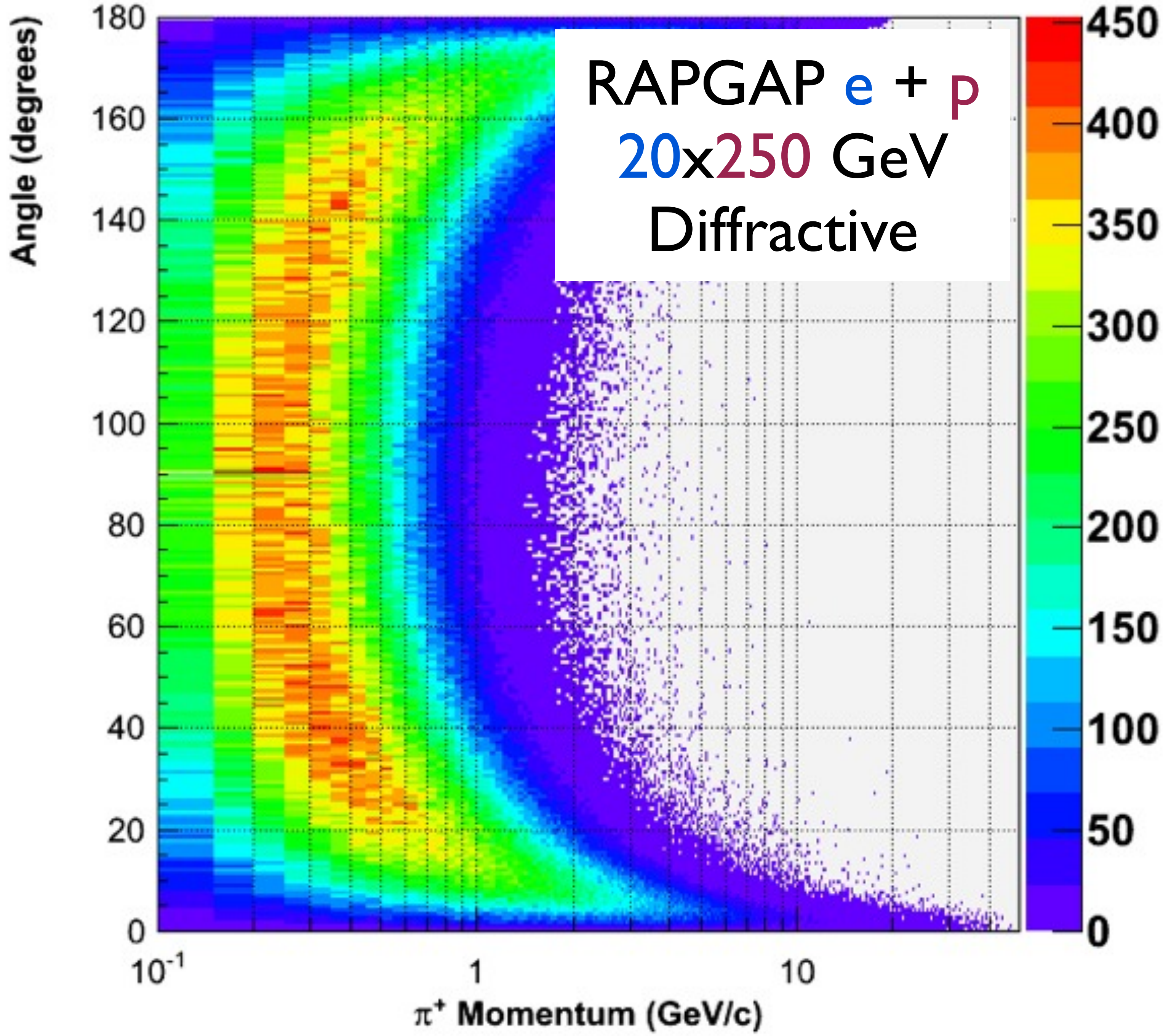
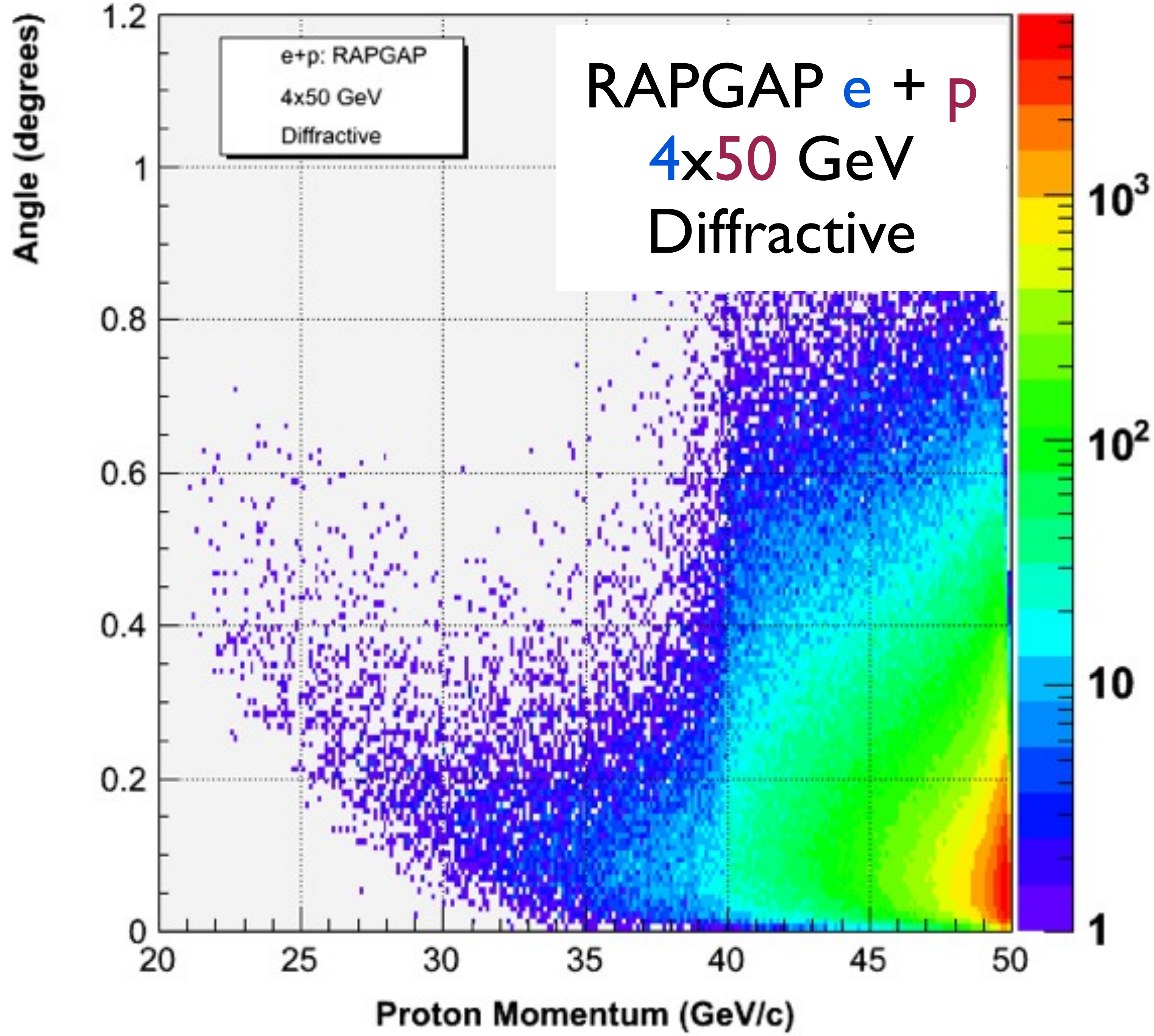


Proton detection

- Always very forward
  - Hard to detect
- Energy dependent
  - **50 GeV: <0.5°**
  - **250 GeV: < 0.2°**



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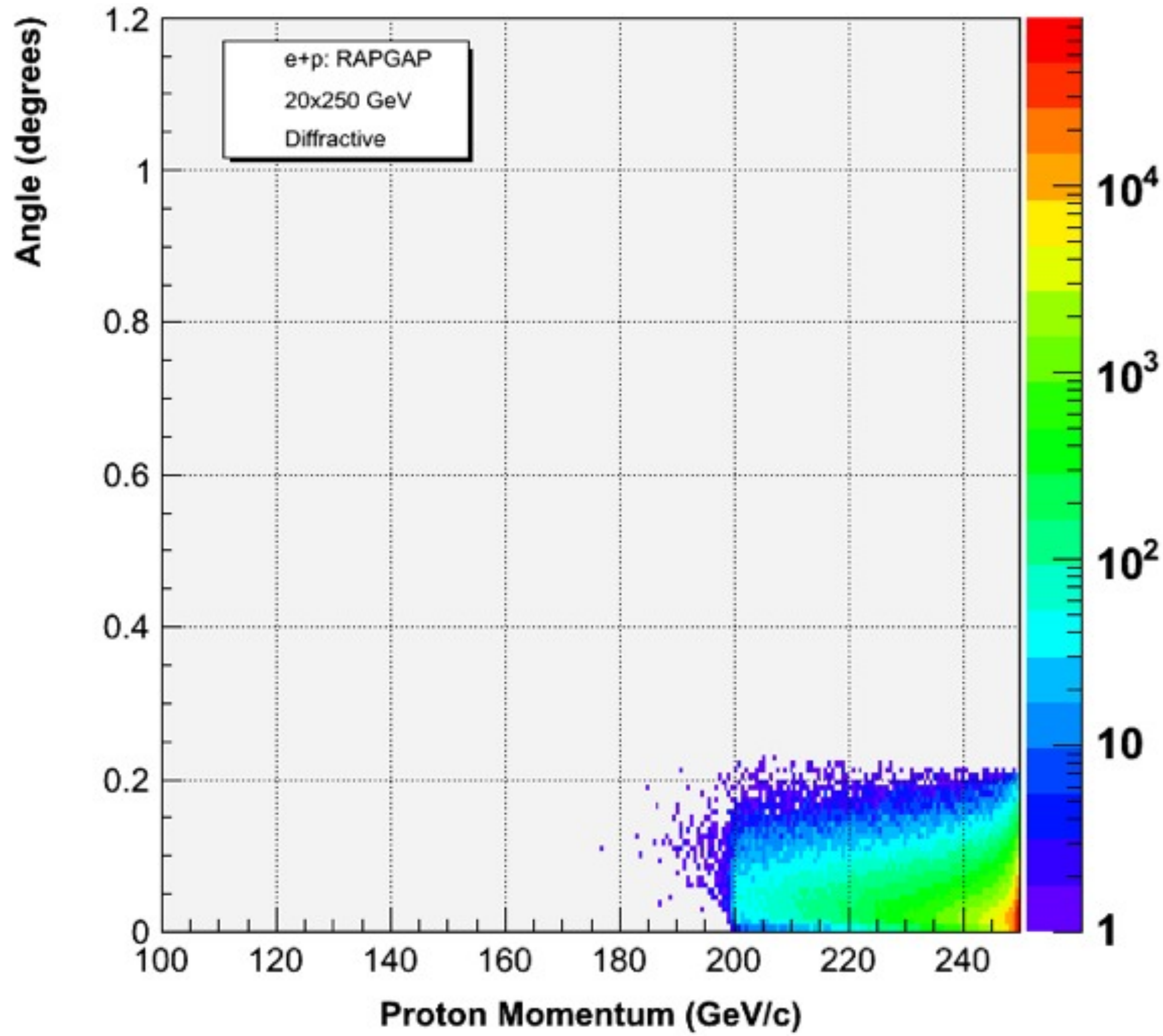
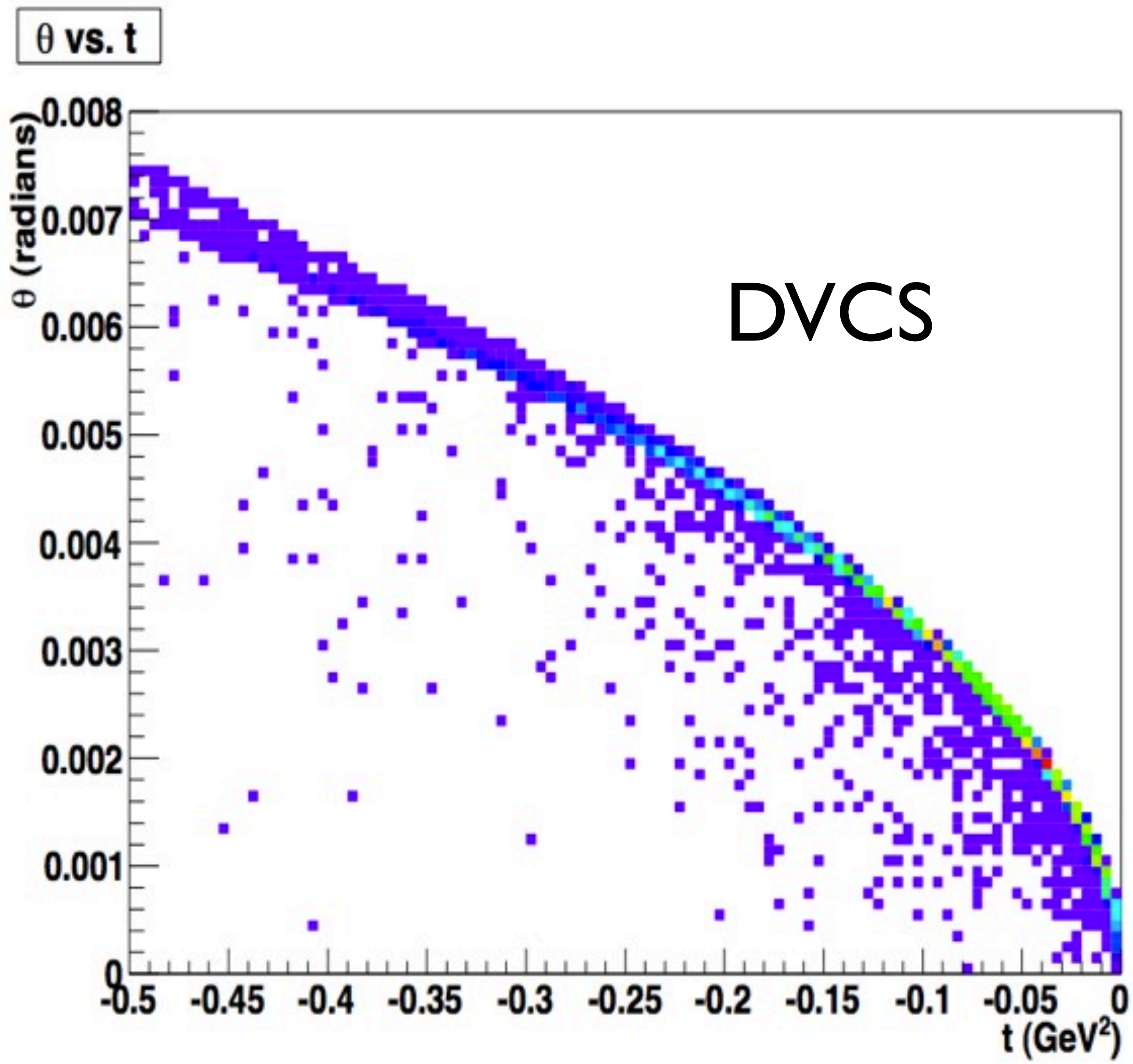


Proton detection

- $t = (p - p`)^2$
- Want to measure a **range** in t
- **Strongly correlated with angle**



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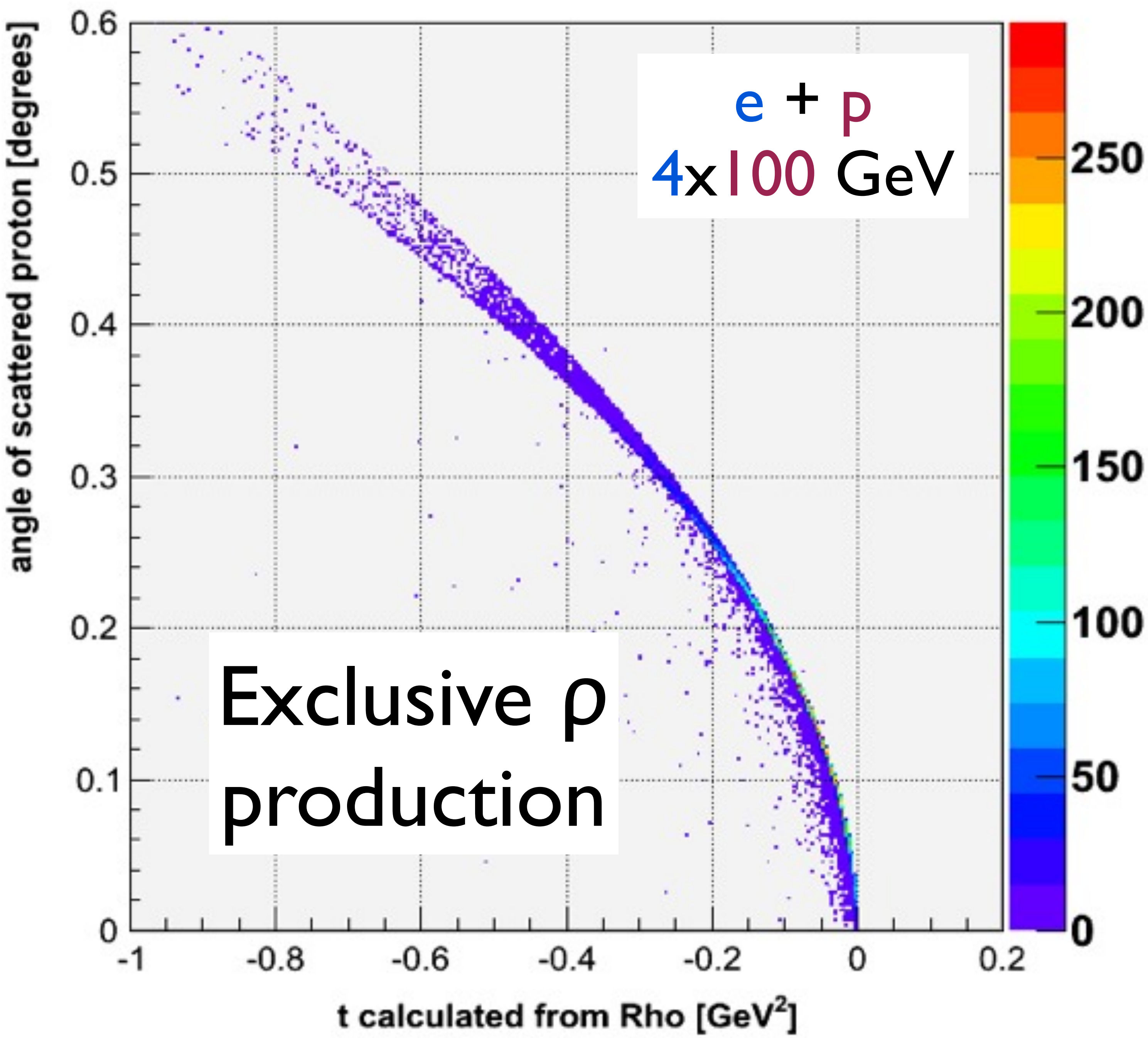
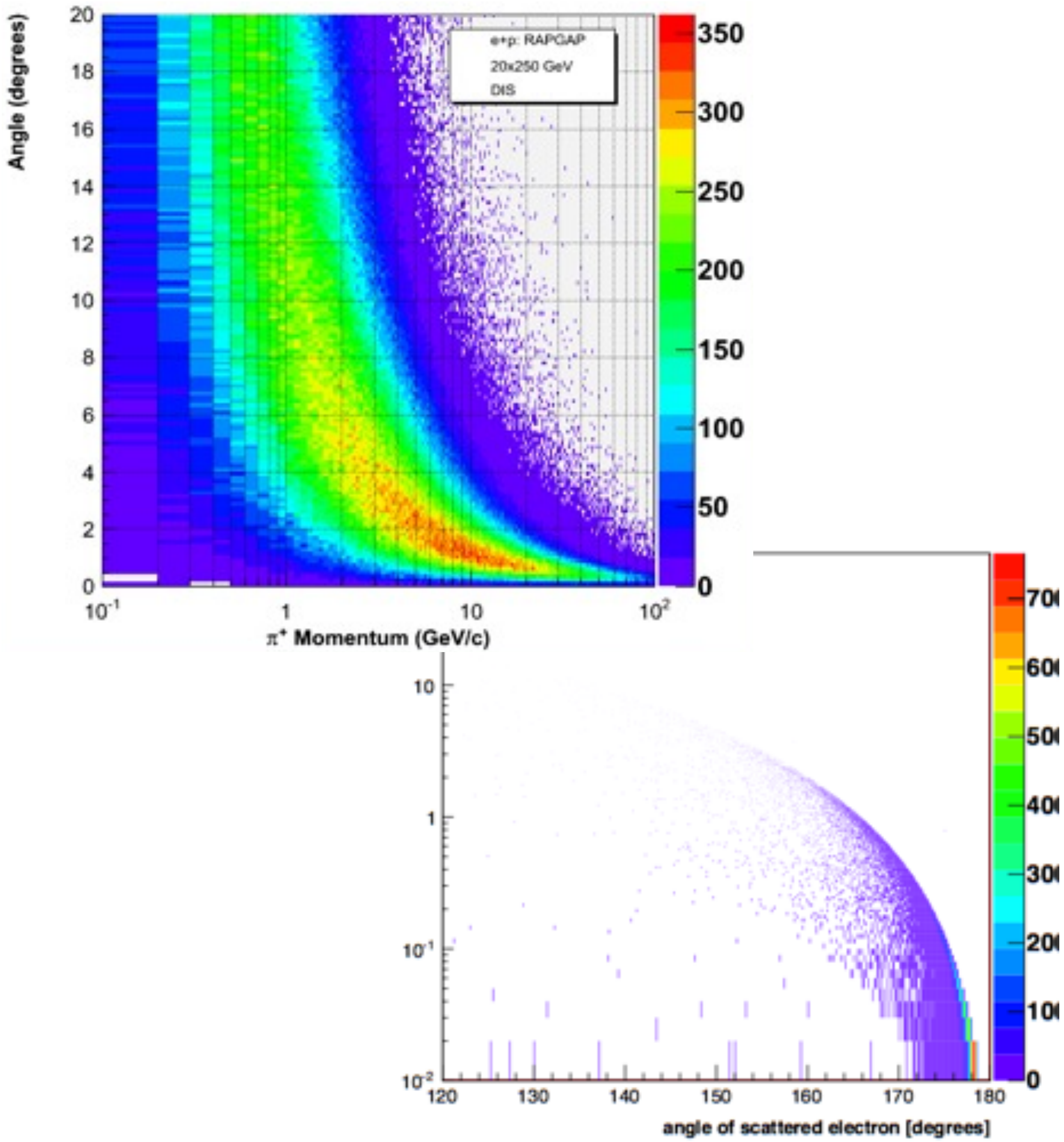
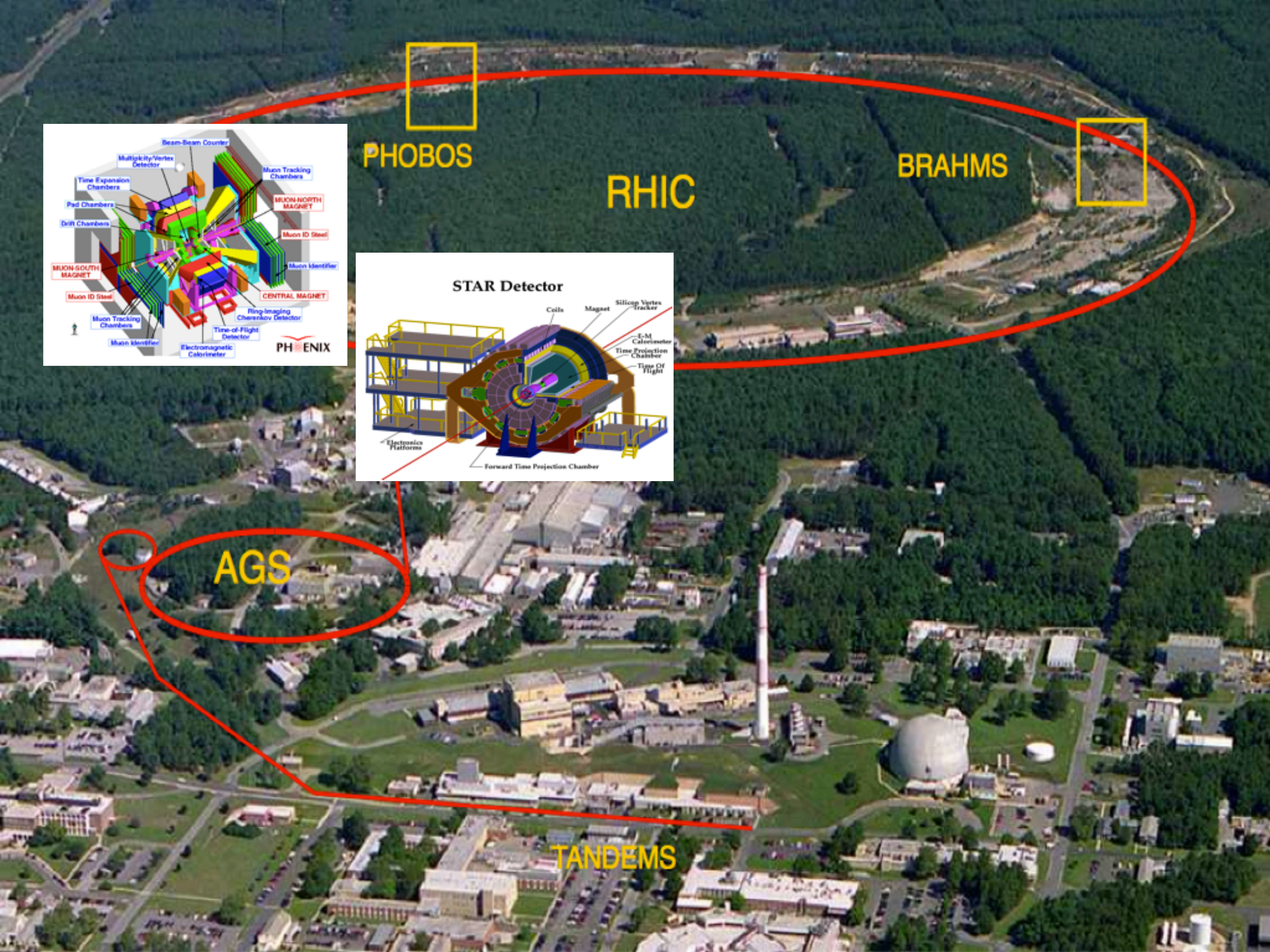


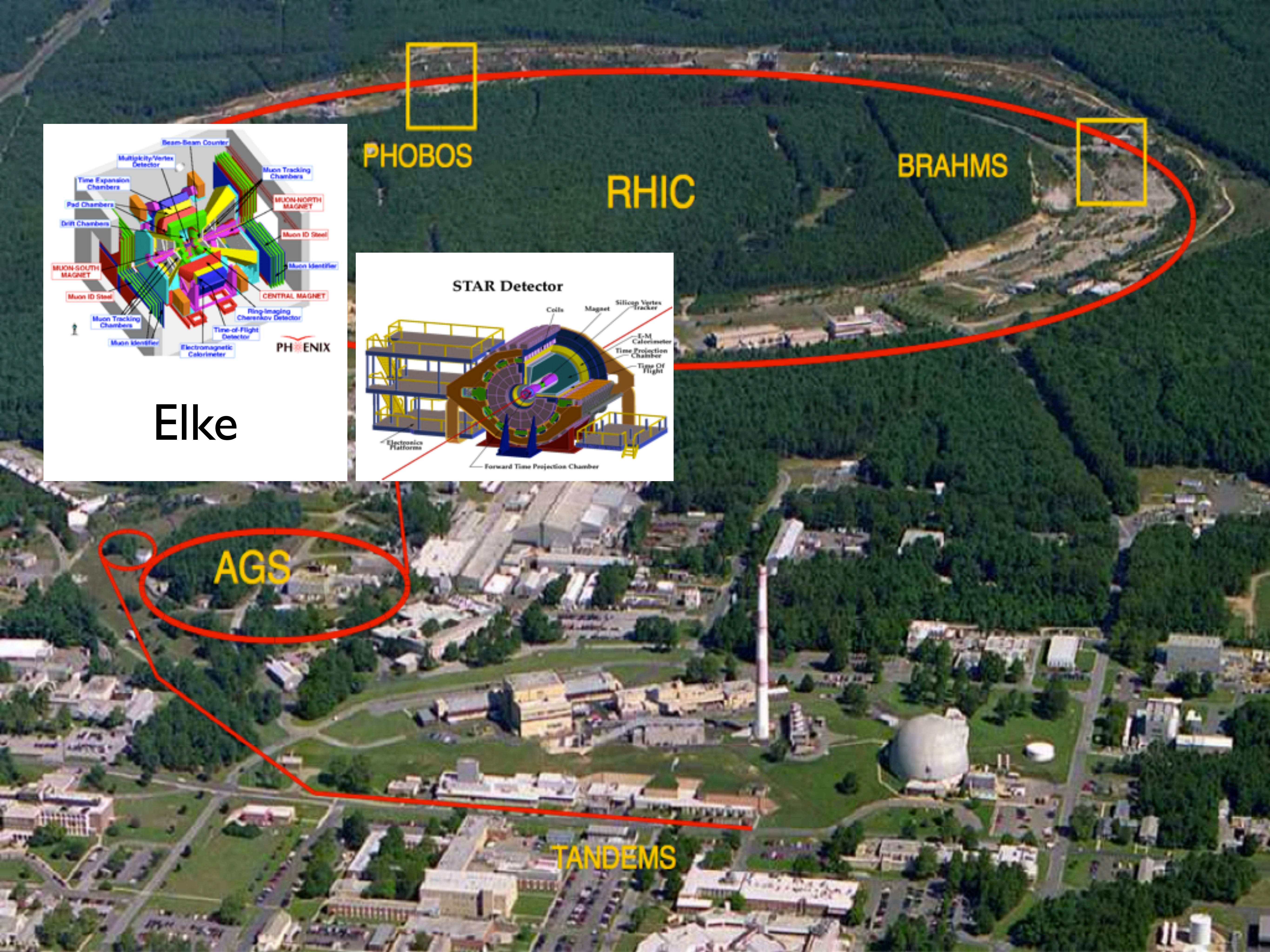
Detector requirements



- Electron detection @ small angles
- Hadron identification @
  - Wide angular range
  - Wide momentum range
- Vertex measurements
- **Resolution**

Integration with RHIC


PHOBOS
RHIC
BRAHMS
Beam-Beam Counter
Multiplicity/Vertex Detector
Time Expansion Chambers
Pad Chambers
Drift Chambers
Muon Tracking Chambers
MUON-NORTH MAGNET
Muon ID Steel
Muon Identifier
MUON-SOUTH MAGNET
Muon ID Steel
CENTRAL MAGNET
Ring-Imaging Cherenkov Detector
Muon Tracking Chambers
Time-of-Flight Detector
Muon Identifier
Electromagnetic Calorimeter
PHENIX
STAR Detector
Coils
Magnet
Silicon Vertex Tracker
E-M Calorimeter
Time Projection Chamber
Time Of Flight
Electronics Platforms
Forward Time Projection Chamber
AGS
TANDEMS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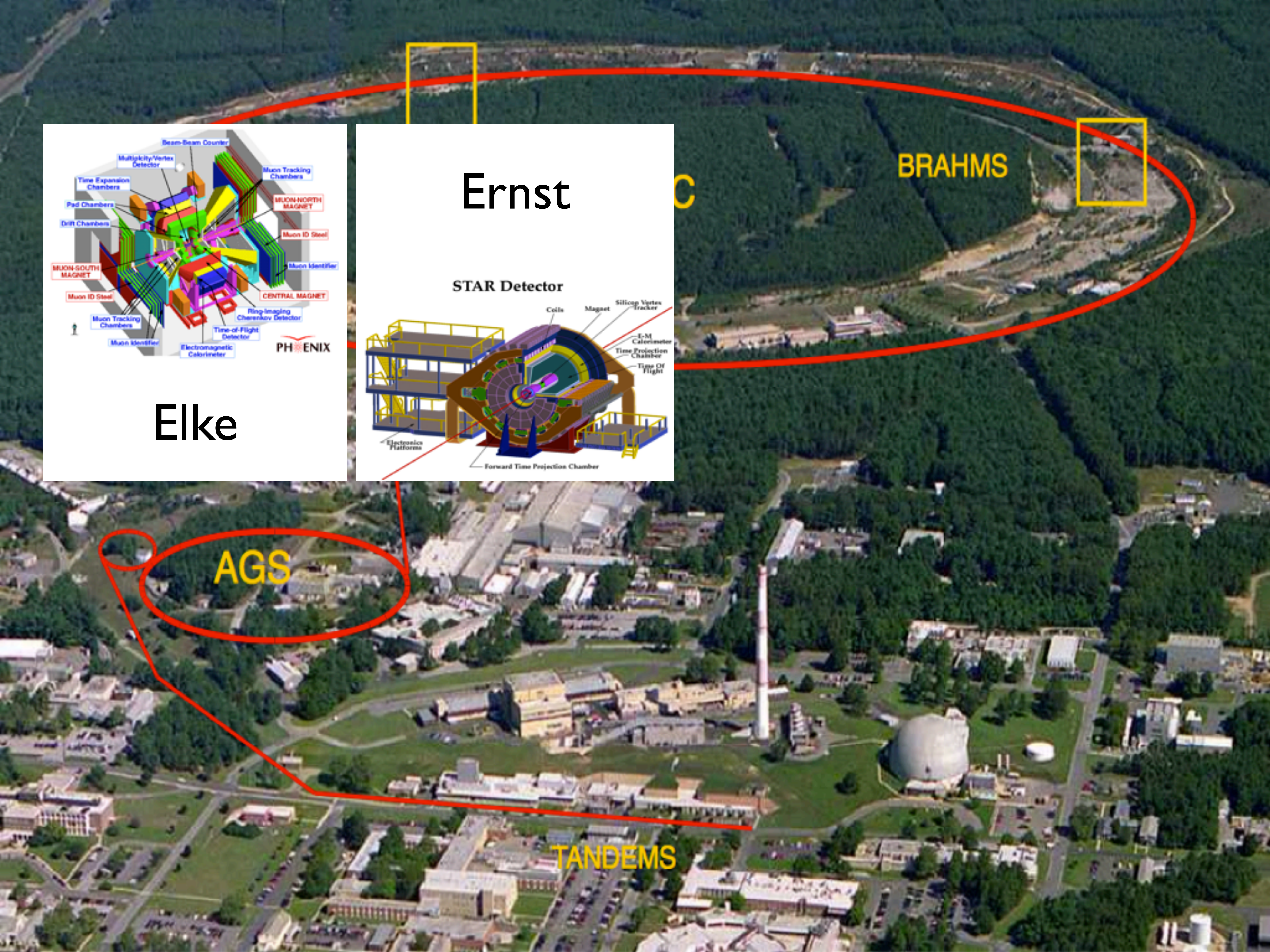
Ernst
C
BRAHMS
Beam-Beam Counter
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Time Expansion Chambers
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MUON-NORTH MAGNET
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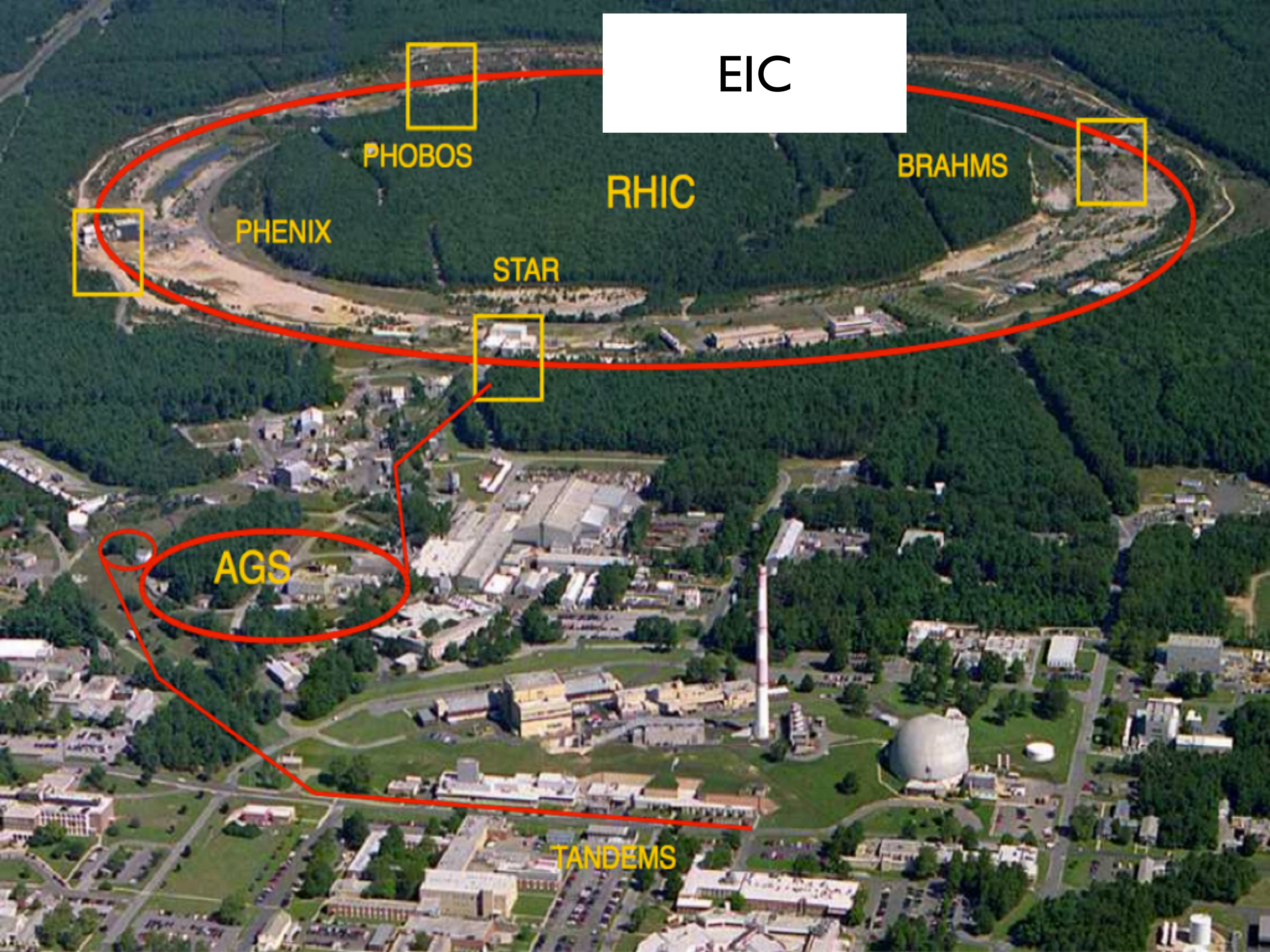
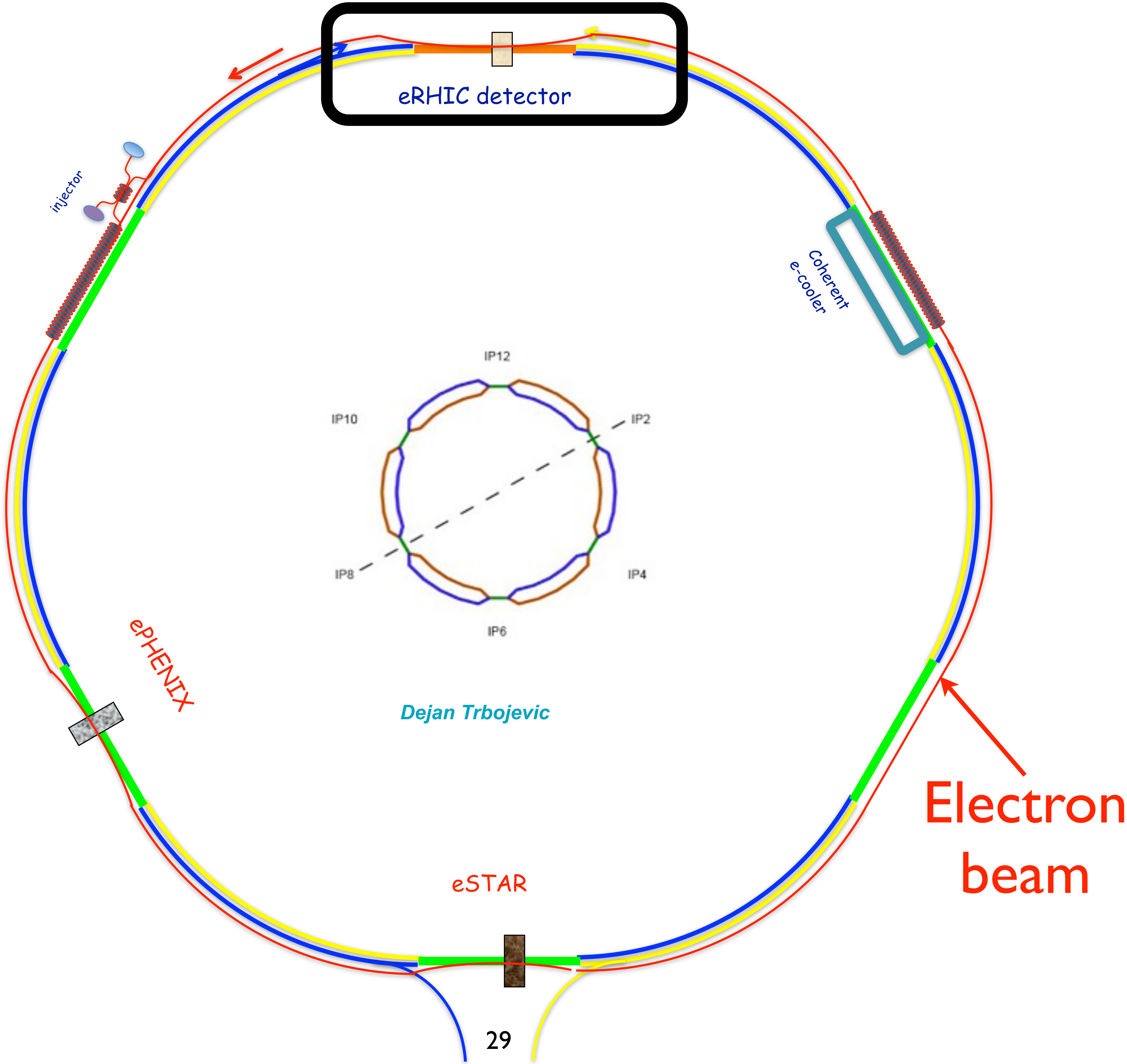
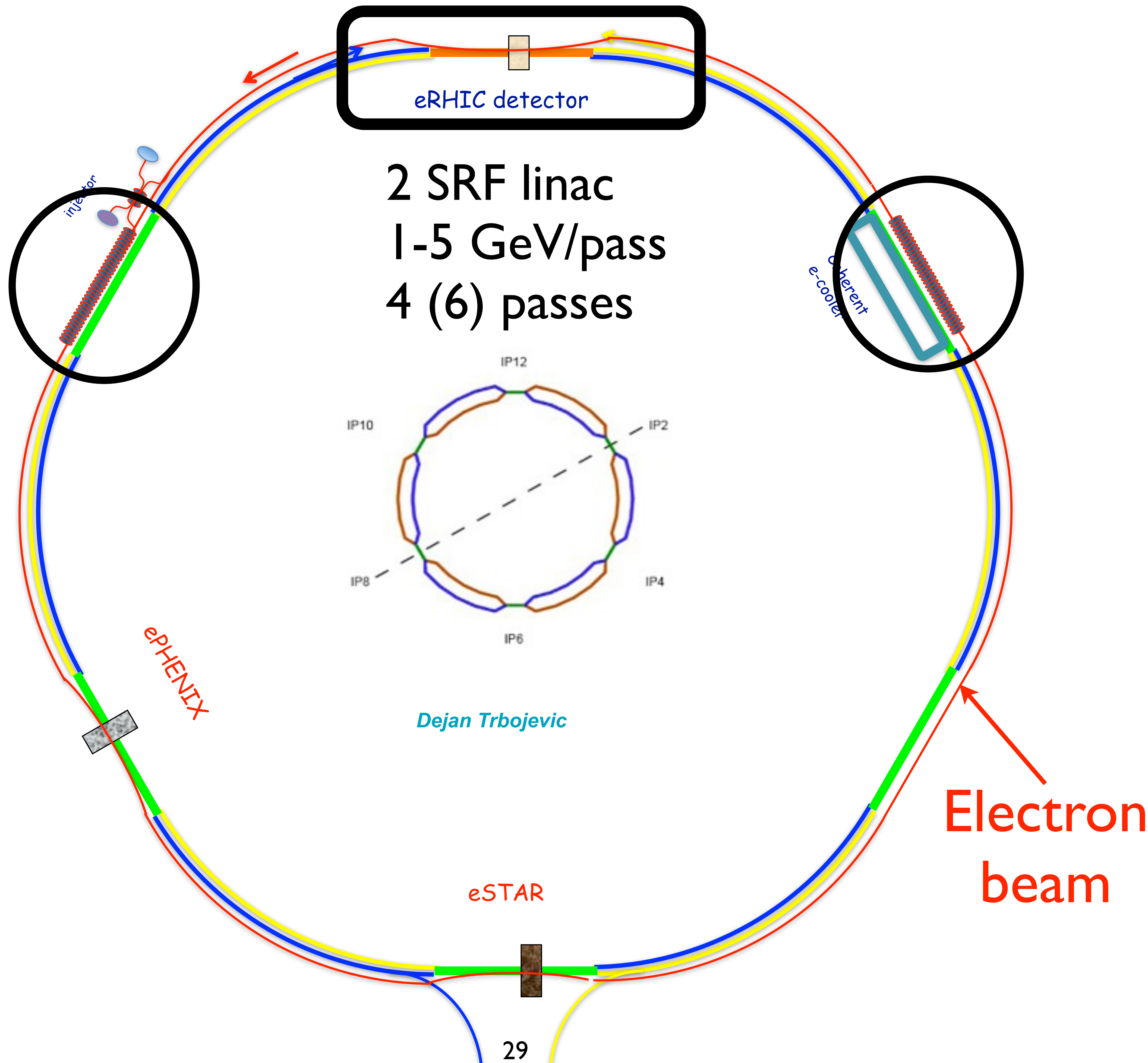
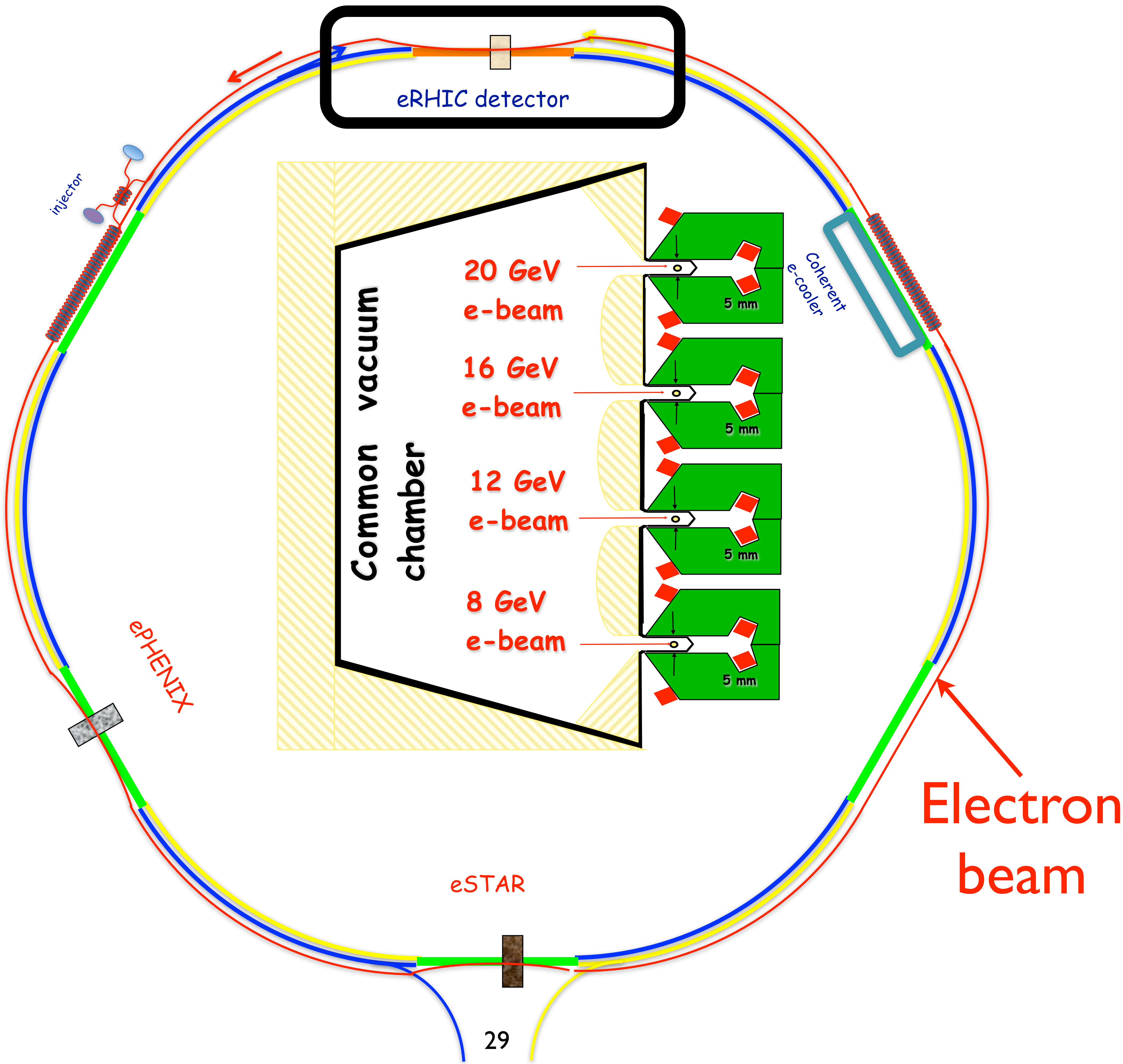
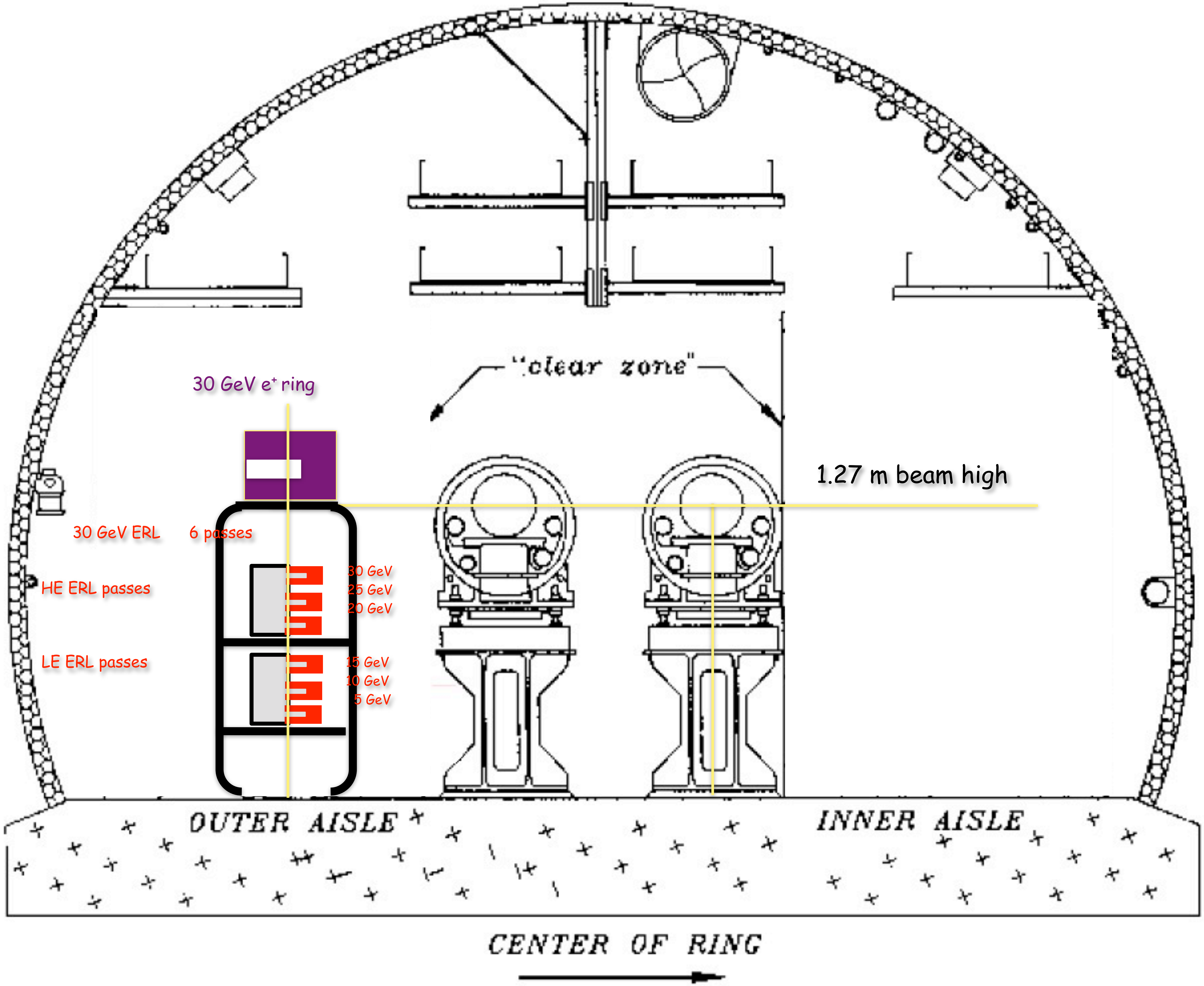

EIC
PHOBOS
RHIC
BRAHMS
PHENIX
STAR
AGS
TANDEMS

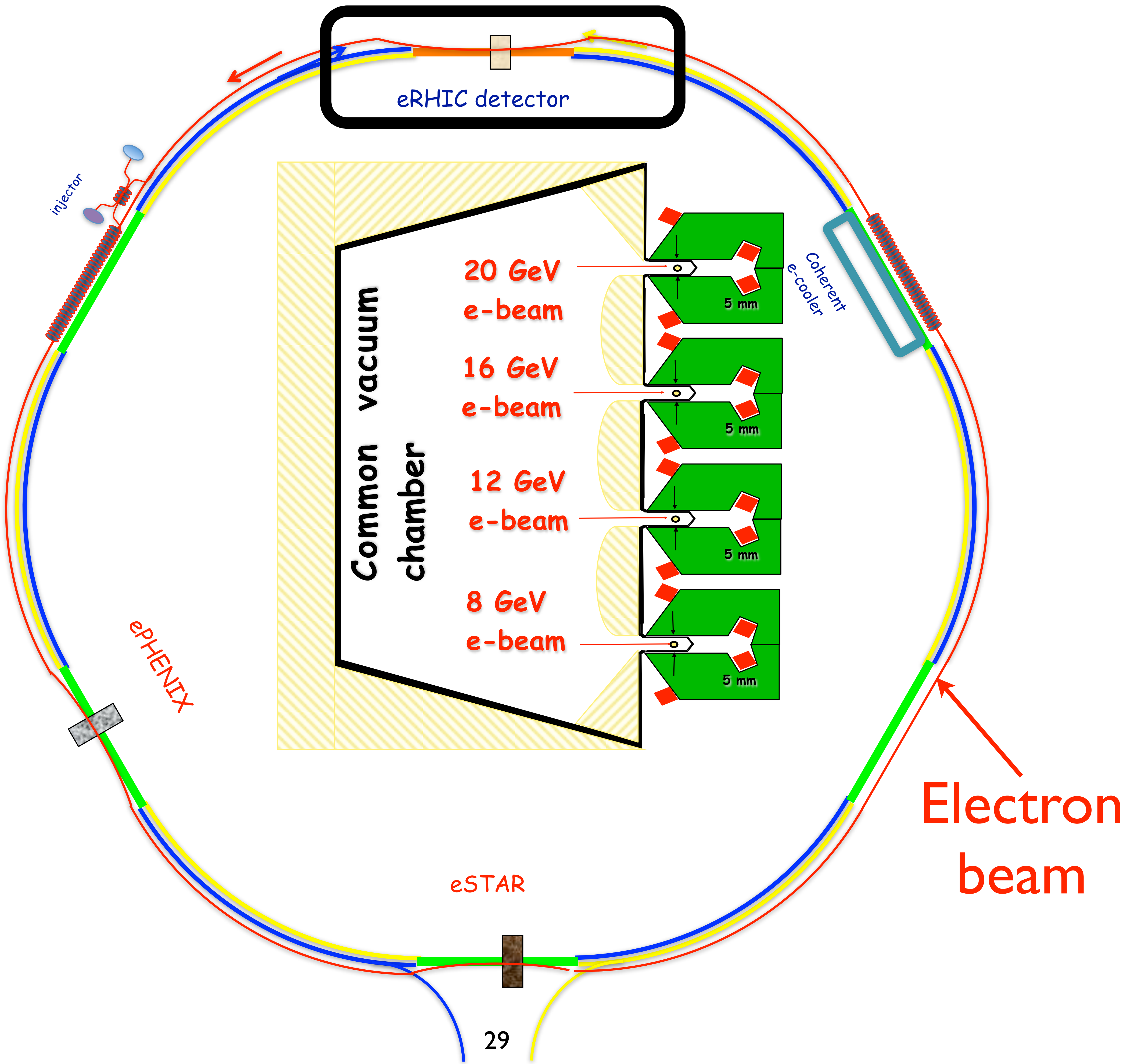

eRHIC detector
injector
Coherent
e-cooler
IP12
IP10
IP2
IP8
IP4
IP6
ePHENIX
Dejan Trbojevic
eSTAR
Electron
beam


eRHIC detector
2 SRF linac
1-5 GeV/pass
4 (6) passes
injector
e-cooler
IP12
IP10
IP2
IP8
IP4
IP6
ePHENIX
Dejan Trbojevic
eSTAR
Electron beam


eRHIC detector
injector
Coherent e-cooler
Common vacuum chamber
20 GeV e-beam
16 GeV e-beam
12 GeV e-beam
8 GeV e-beam
5 mm
5 mm
5 mm
5 mm
ePHENIX
eSTAR
Electron beam



"clear zone"
30 GeV e+ ring
1.27 m beam high
30 GeV ERL
6 passes
HE ERL passes
30 GeV
25 GeV
20 GeV
LE ERL passes
15 GeV
10 GeV
5 GeV
OUTER AISLE
INNER AISLE
CENTER OF RING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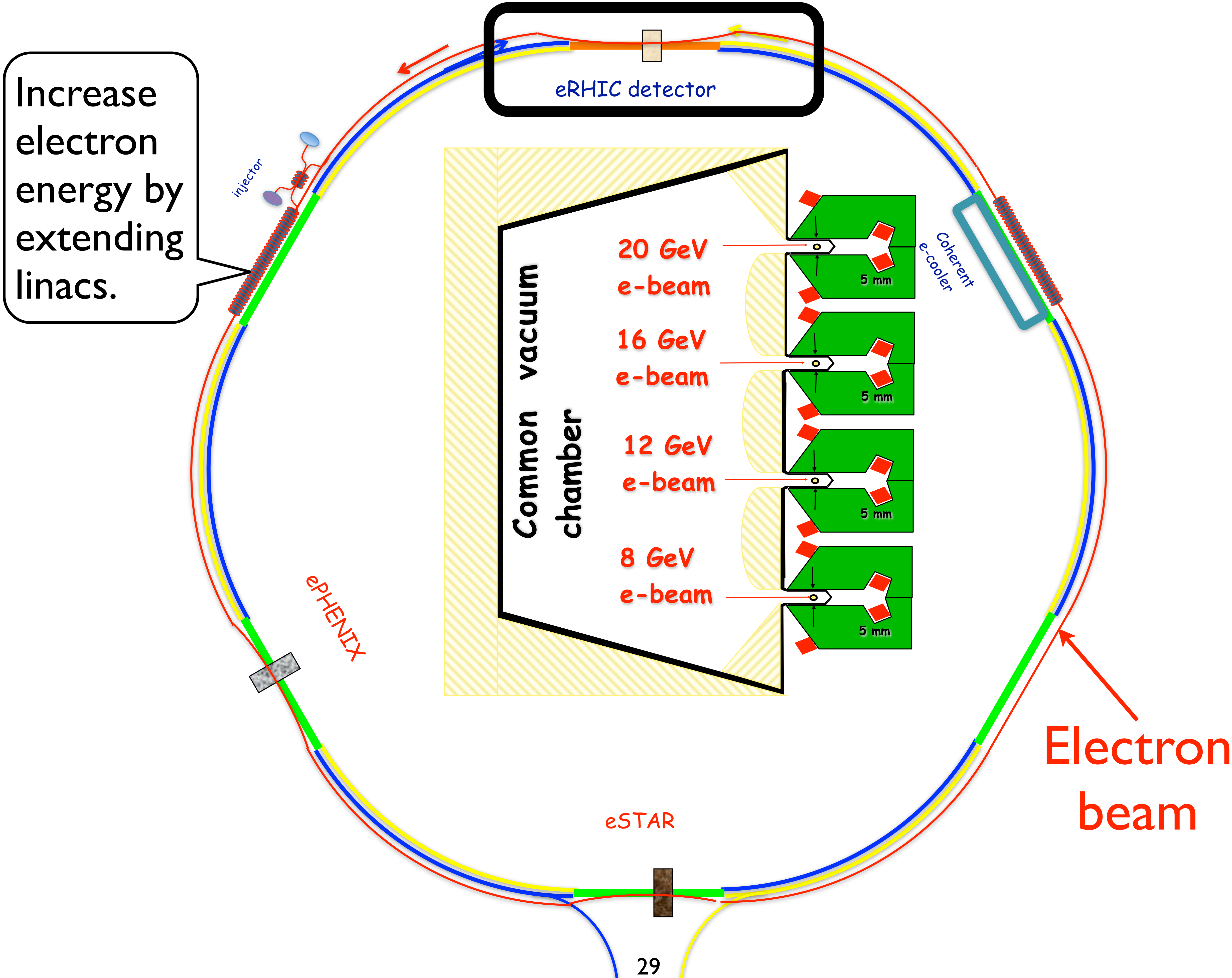
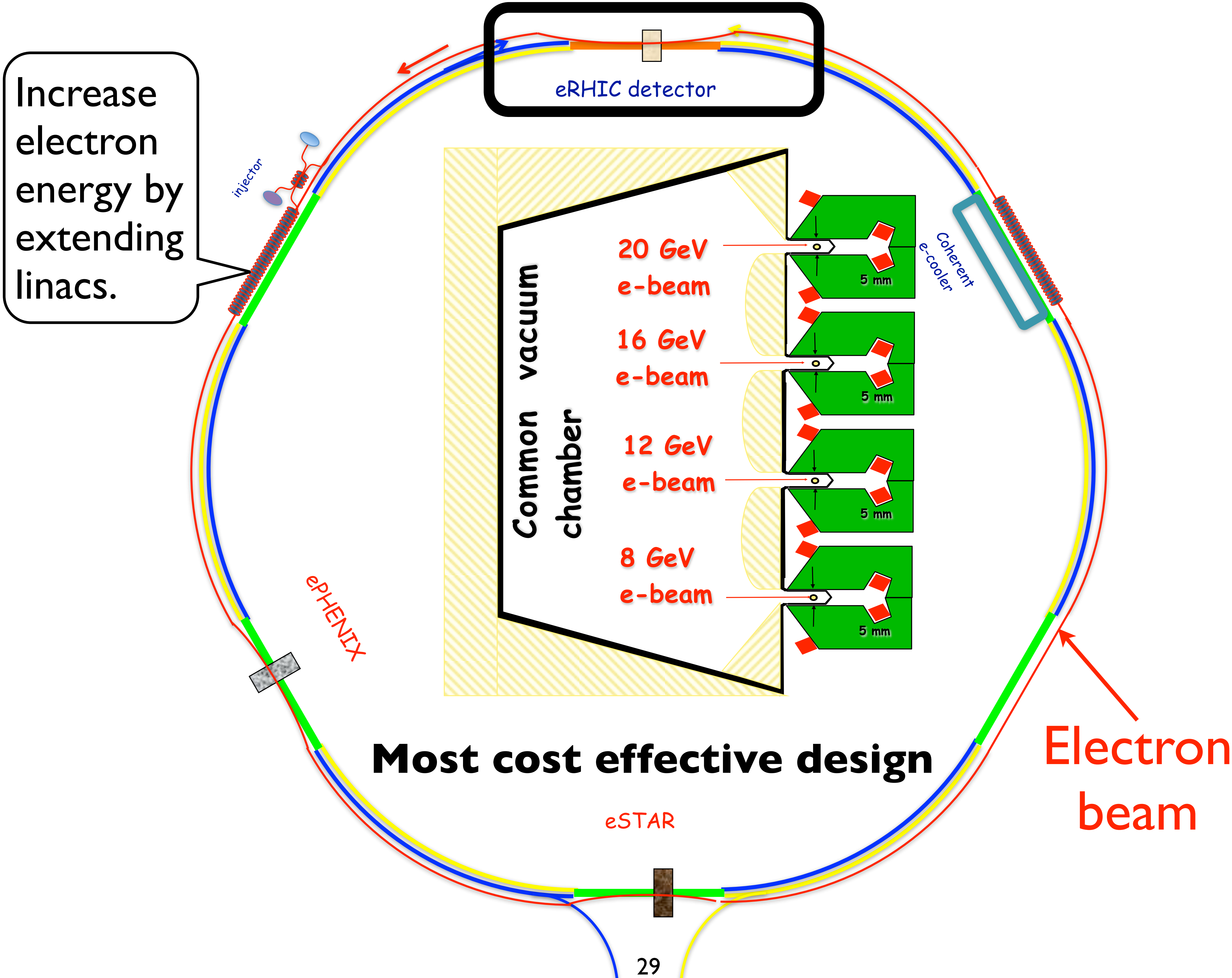


Increase electron energy by extending linacs.
eRHIC detector
injector
Coherent e-cooler
Common vacuum chamber
20 GeV e-beam
16 GeV e-beam
12 GeV e-beam
8 GeV e-beam
5 mm
5 mm
5 mm
5 mm
ePHENIX
eSTAR
Electron beam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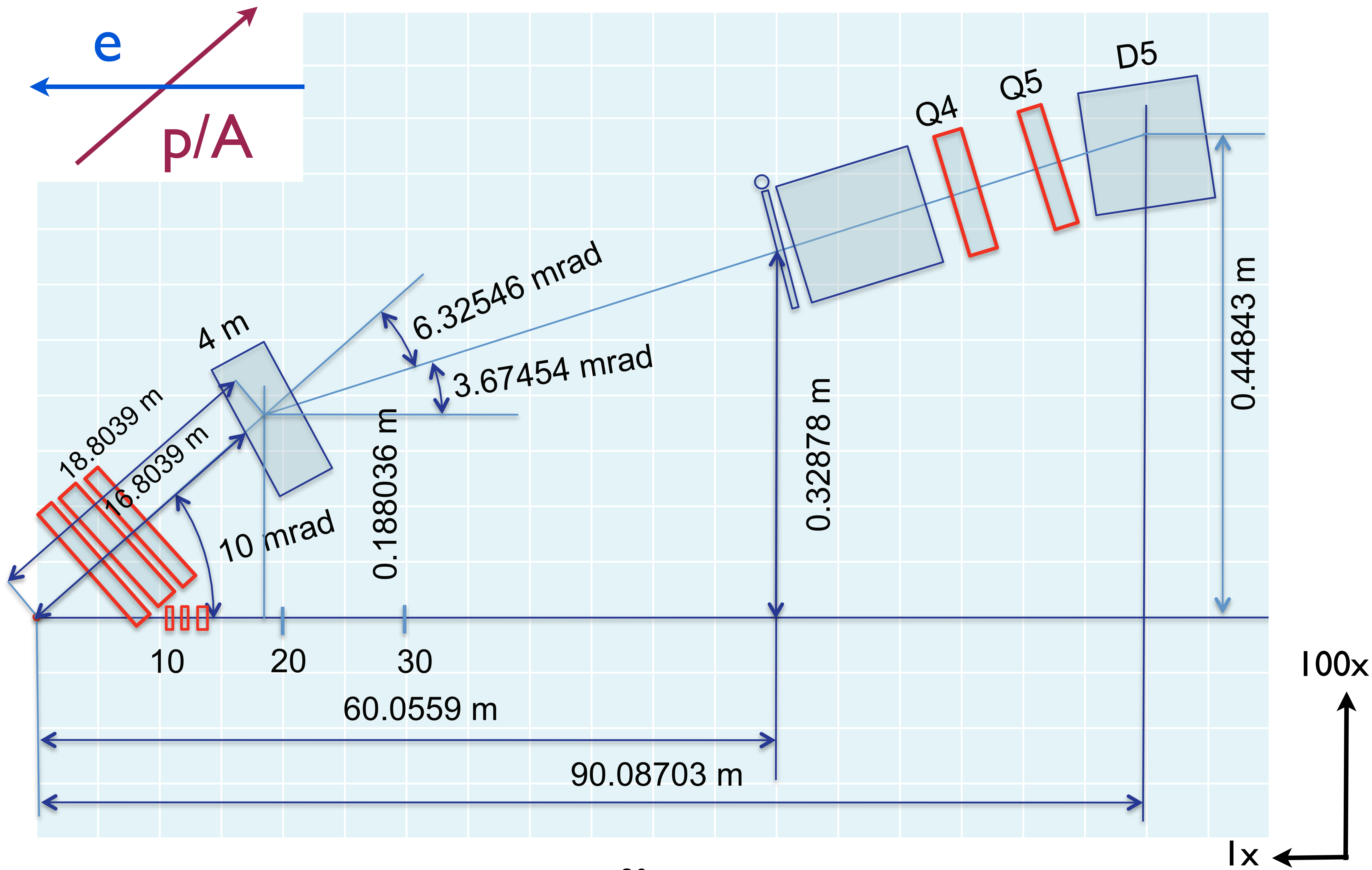
eRHIC detector
injector
Coherent e-cooler
20 GeV e-beam
16 GeV e-beam
12 GeV e-beam
8 GeV e-beam
5 mm
5 mm
5 mm
5 mm
Common vacuum chamber
ePHENIX
Most cost effective design
eSTAR
Electron beam

Interaction point layout



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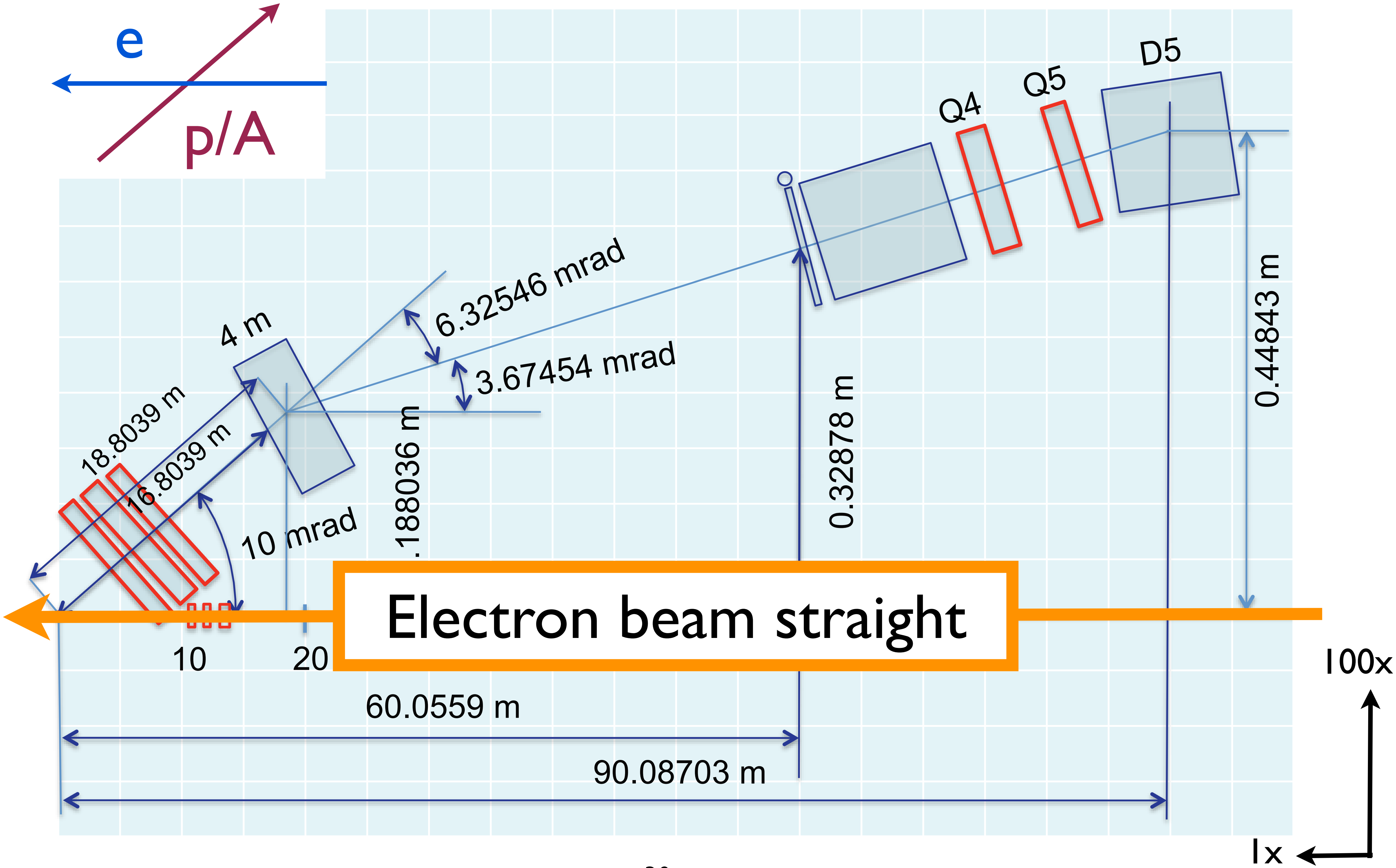

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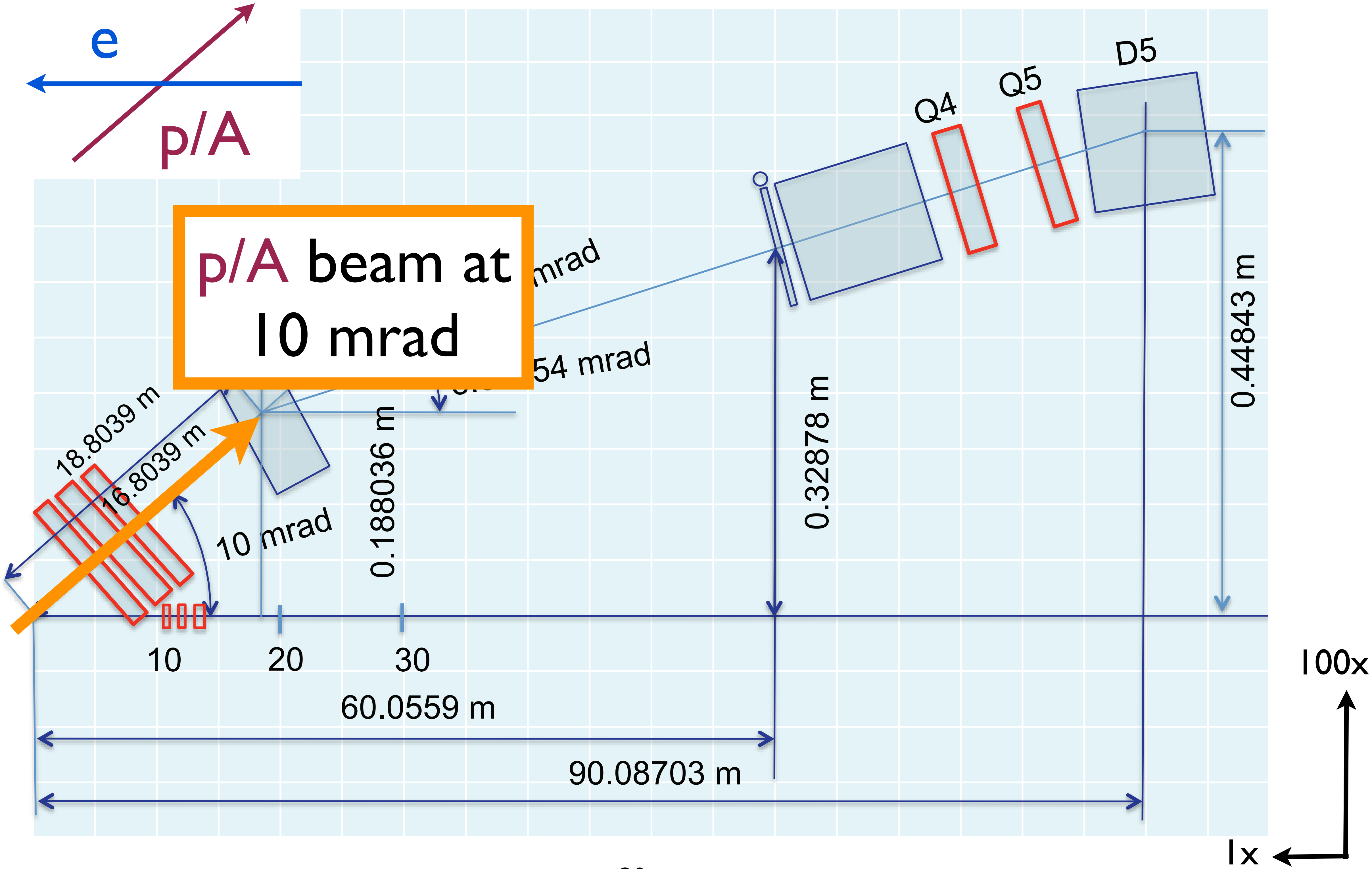

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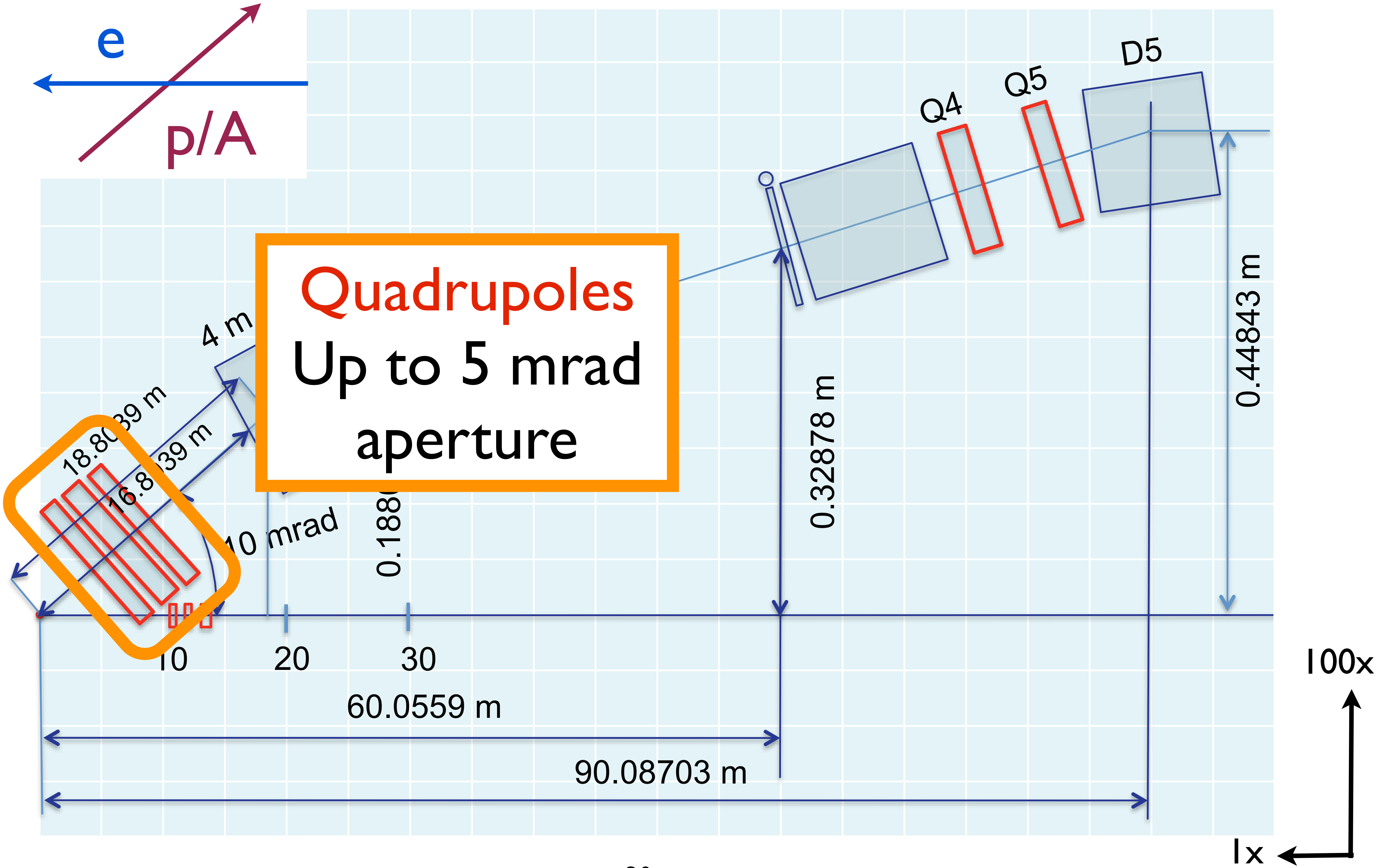

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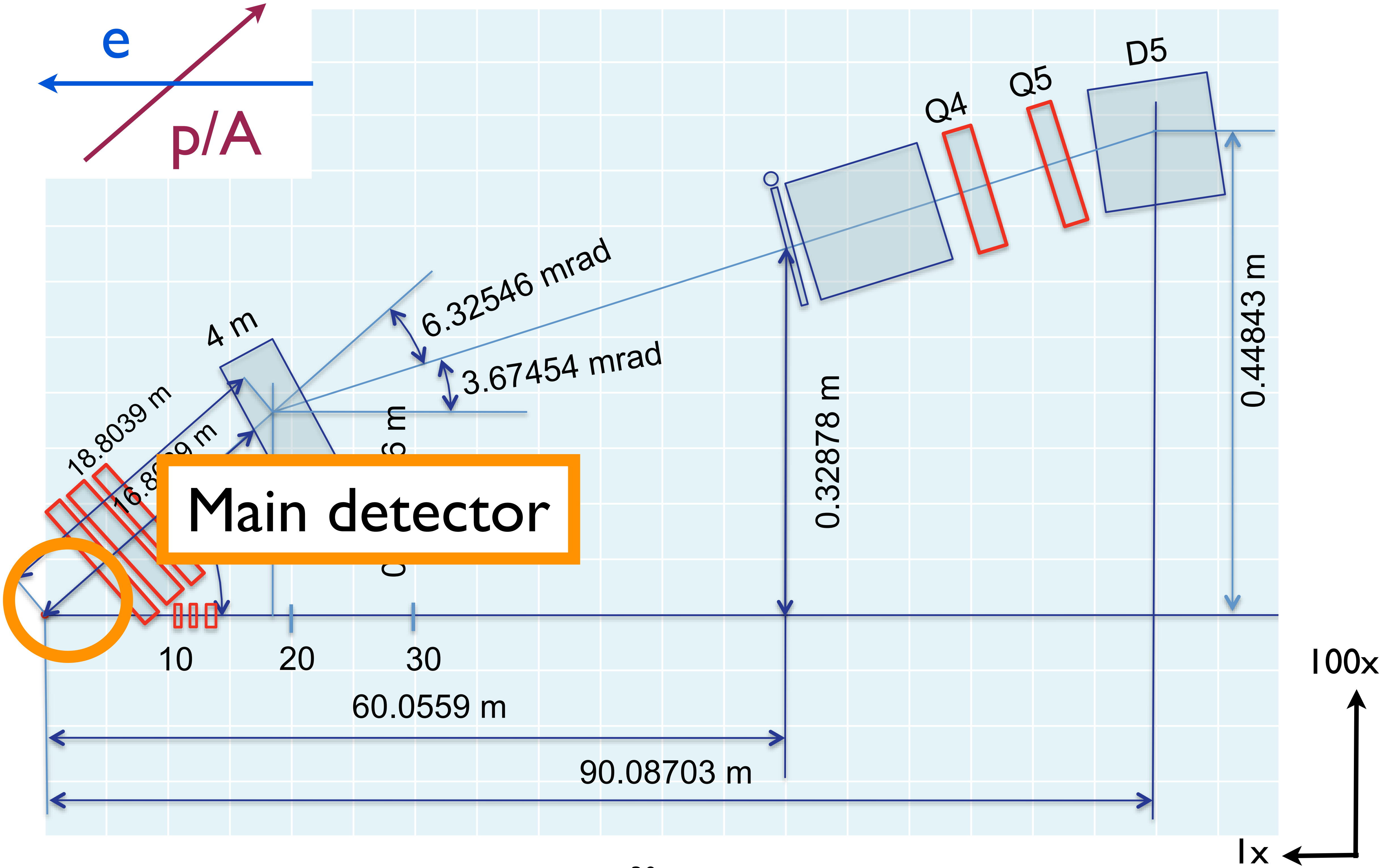

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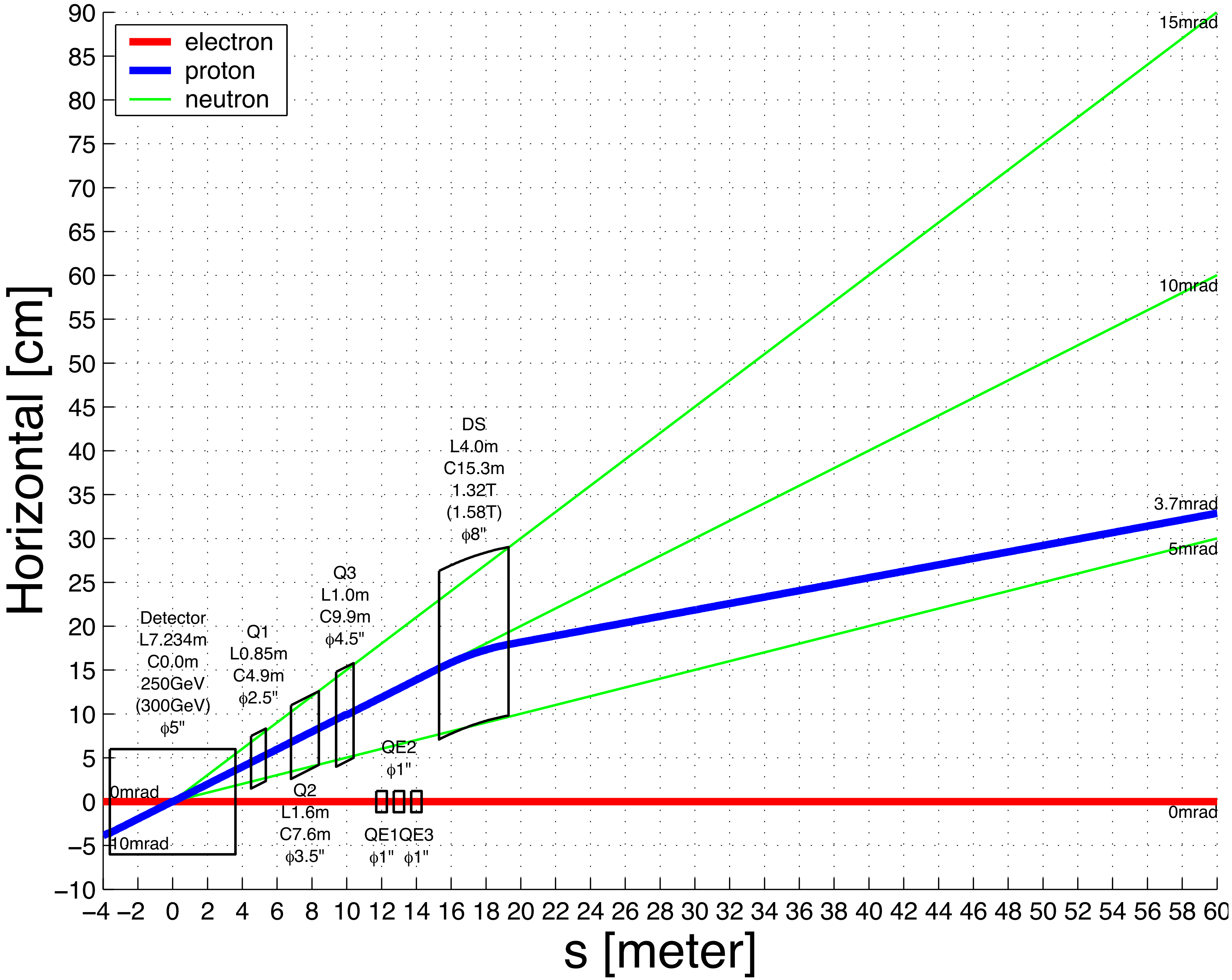
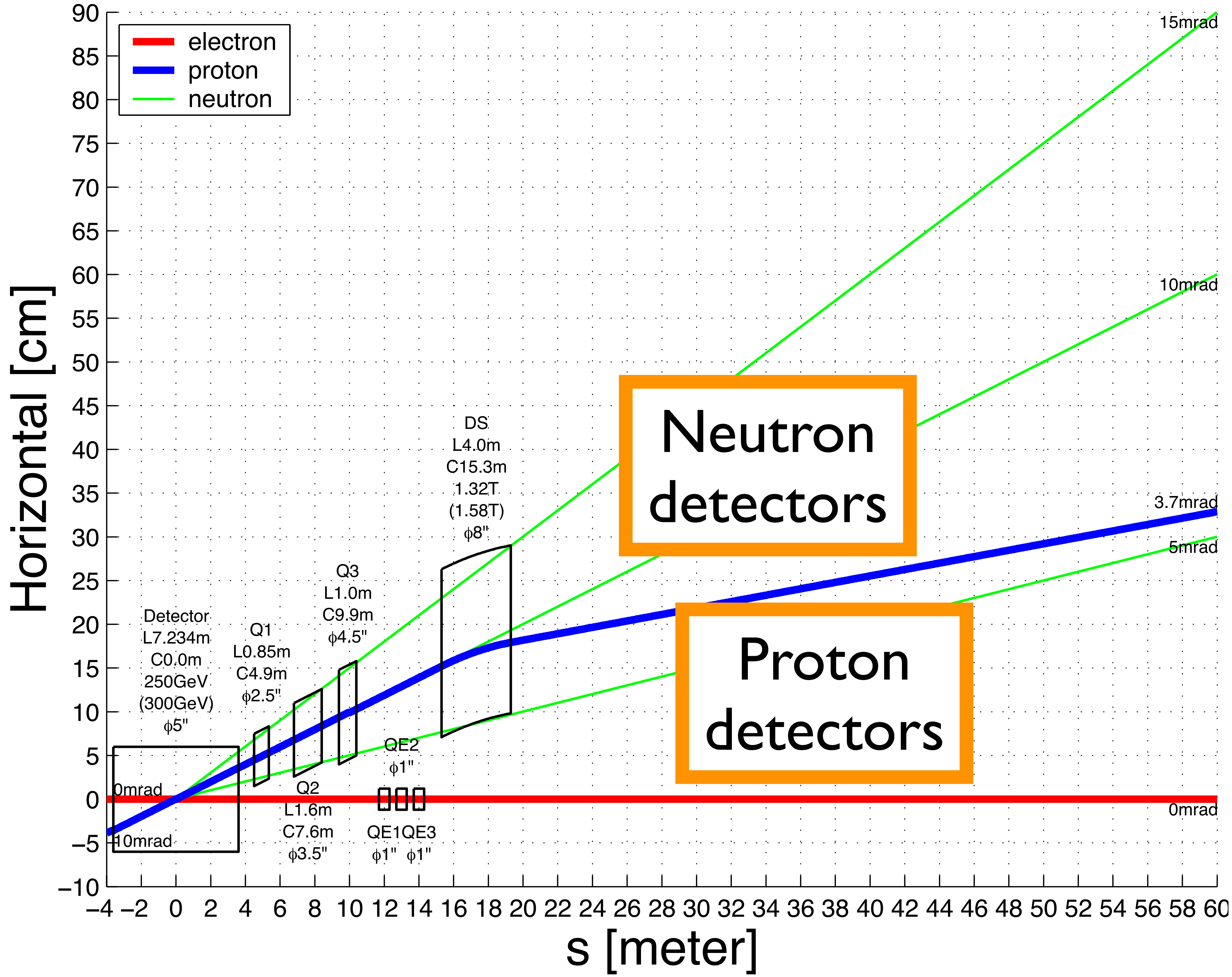
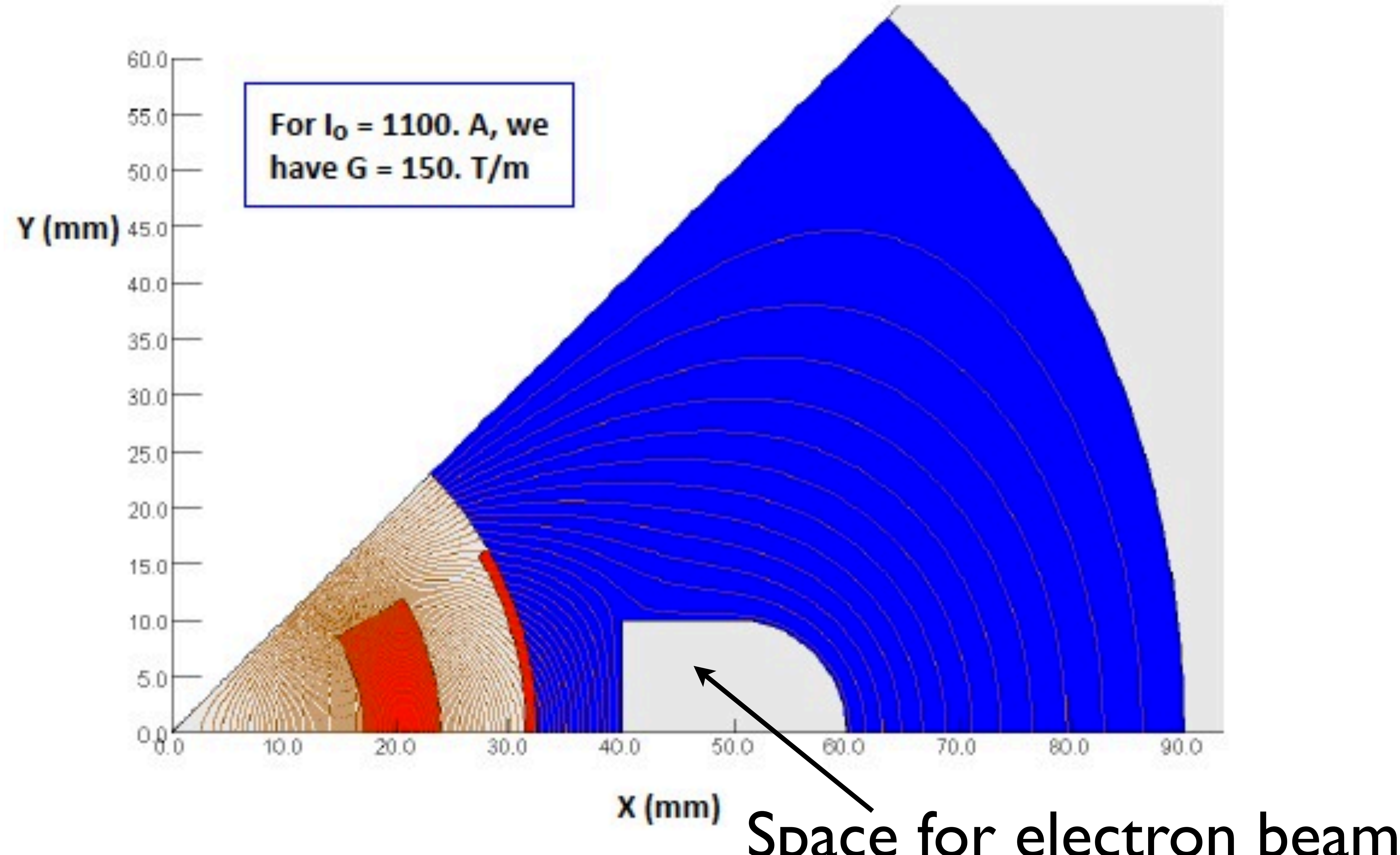


Interaction point layout



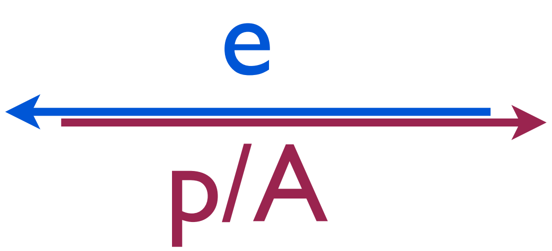
Quadrupole

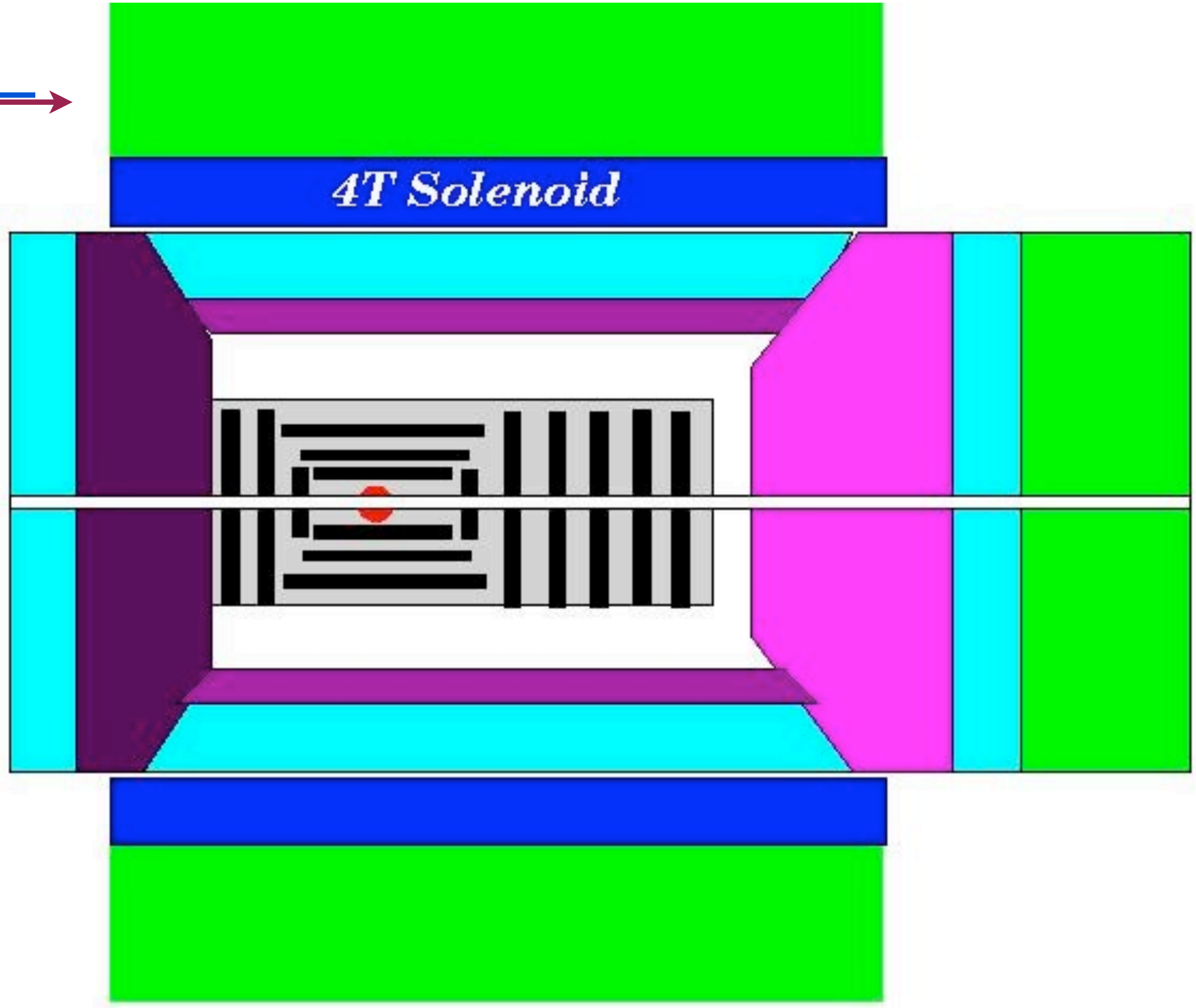


For I_o = 1100. A, we have G = 150. T/m
Y (mm)
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
X (mm)
Space for electron beam

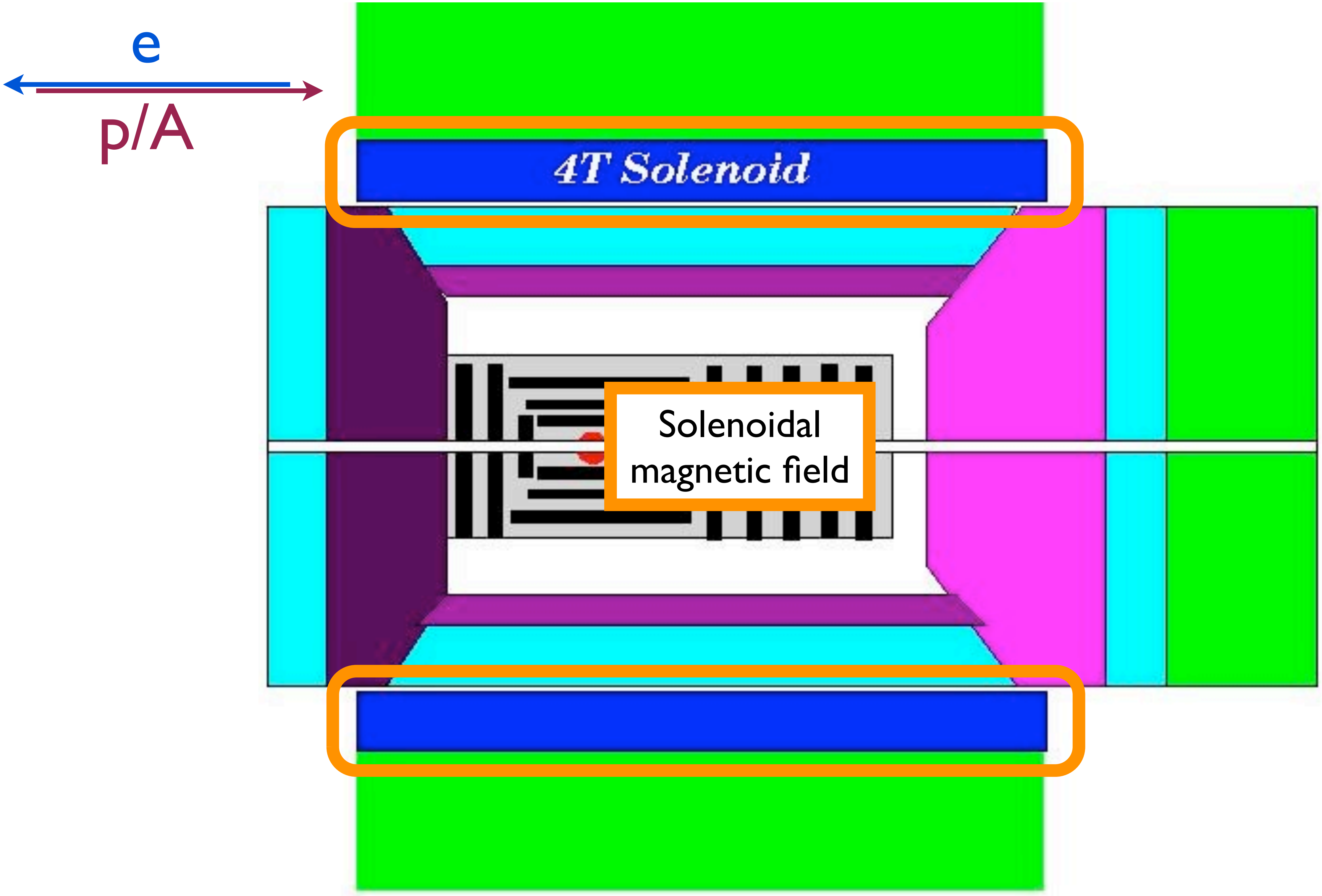
Detector design

Main detector

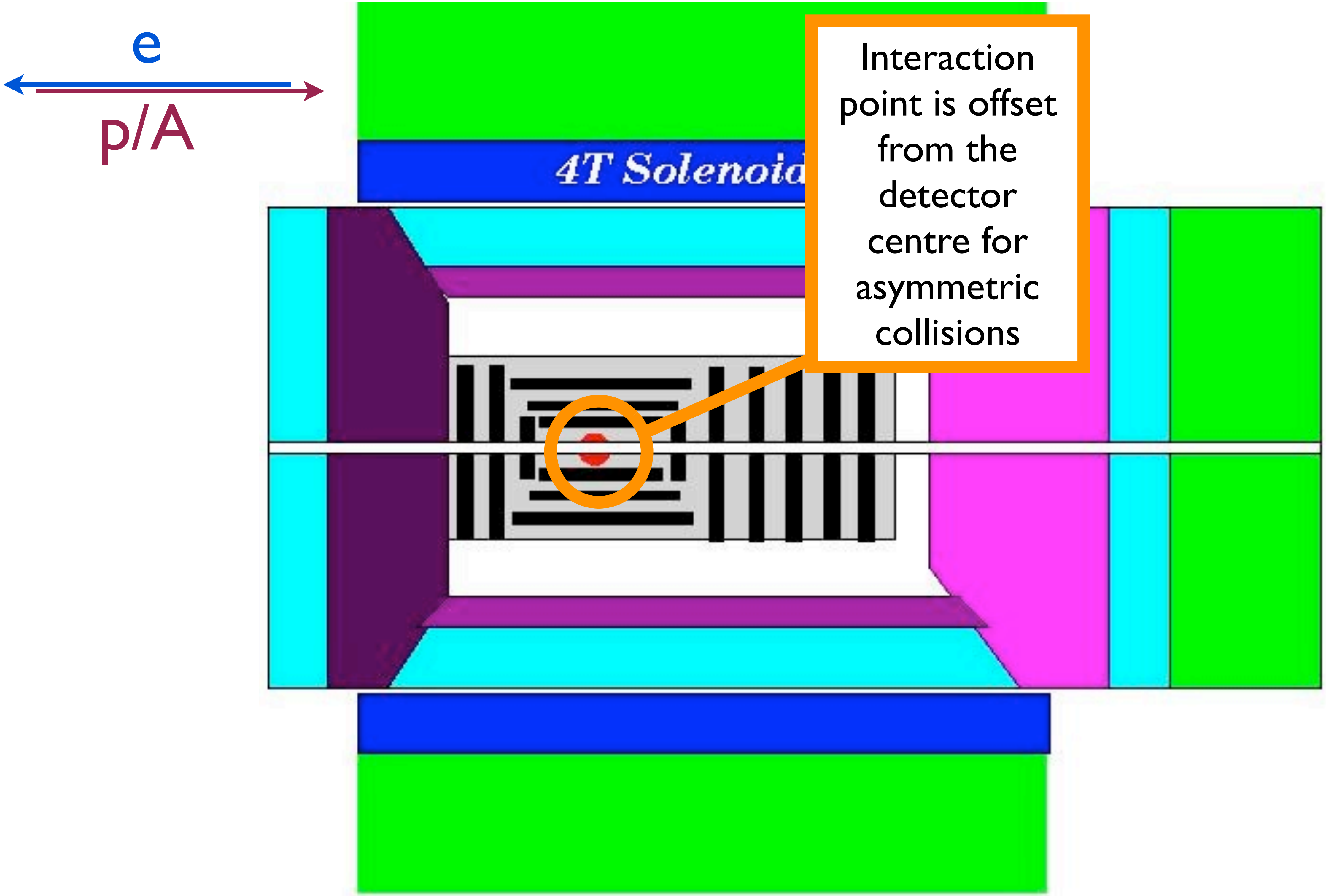




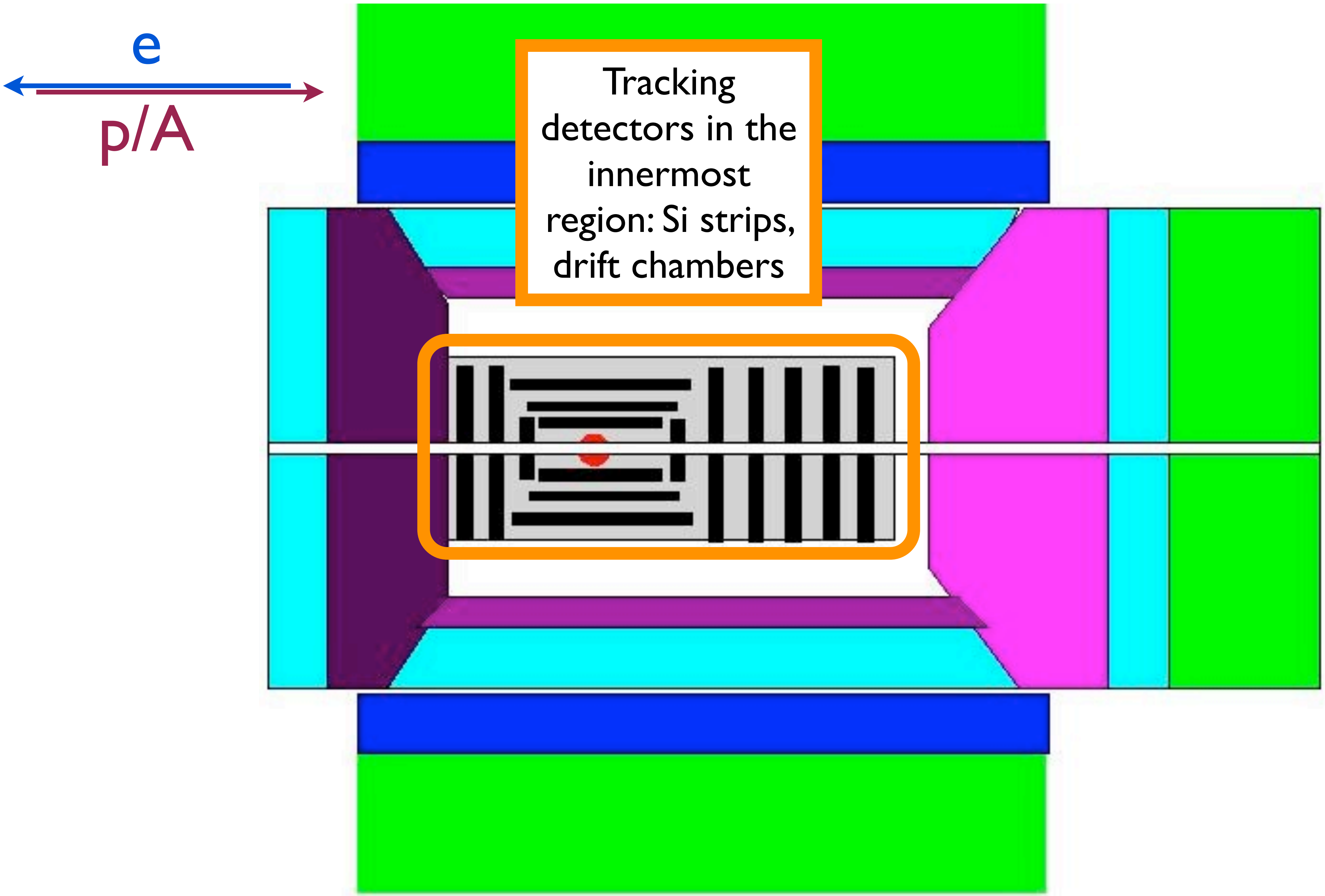
Main detector



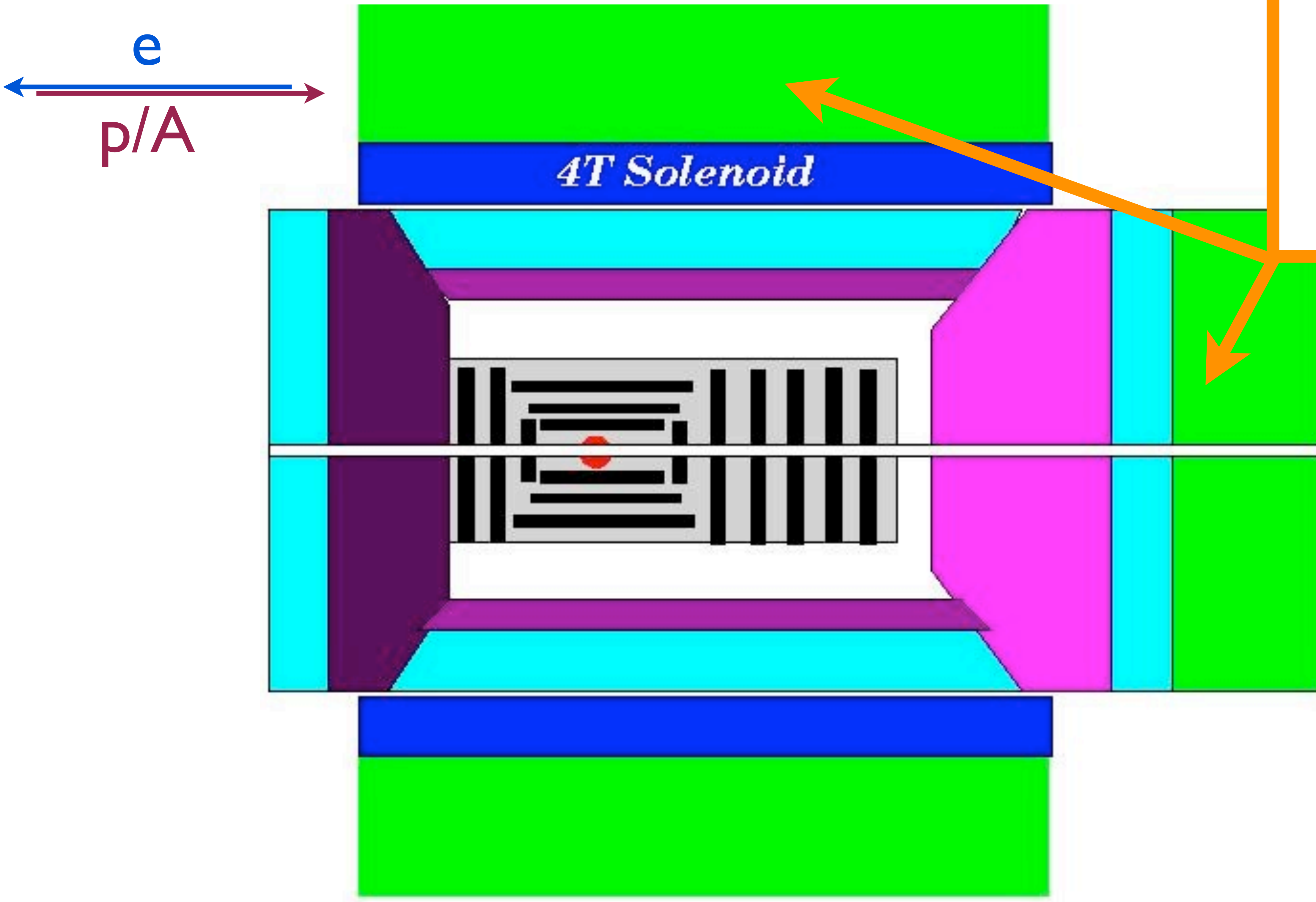
Main detector



Main detector

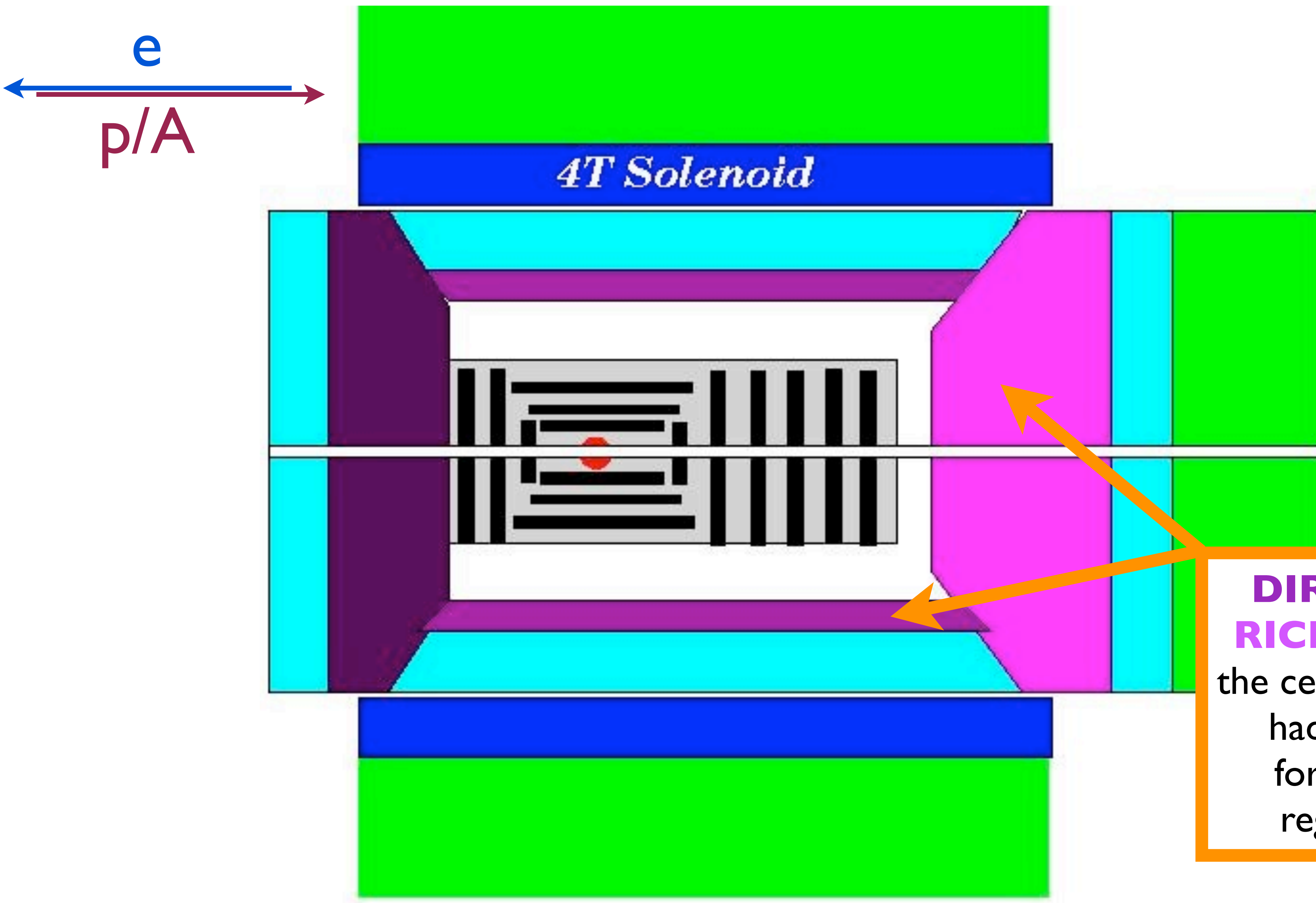


Main detector



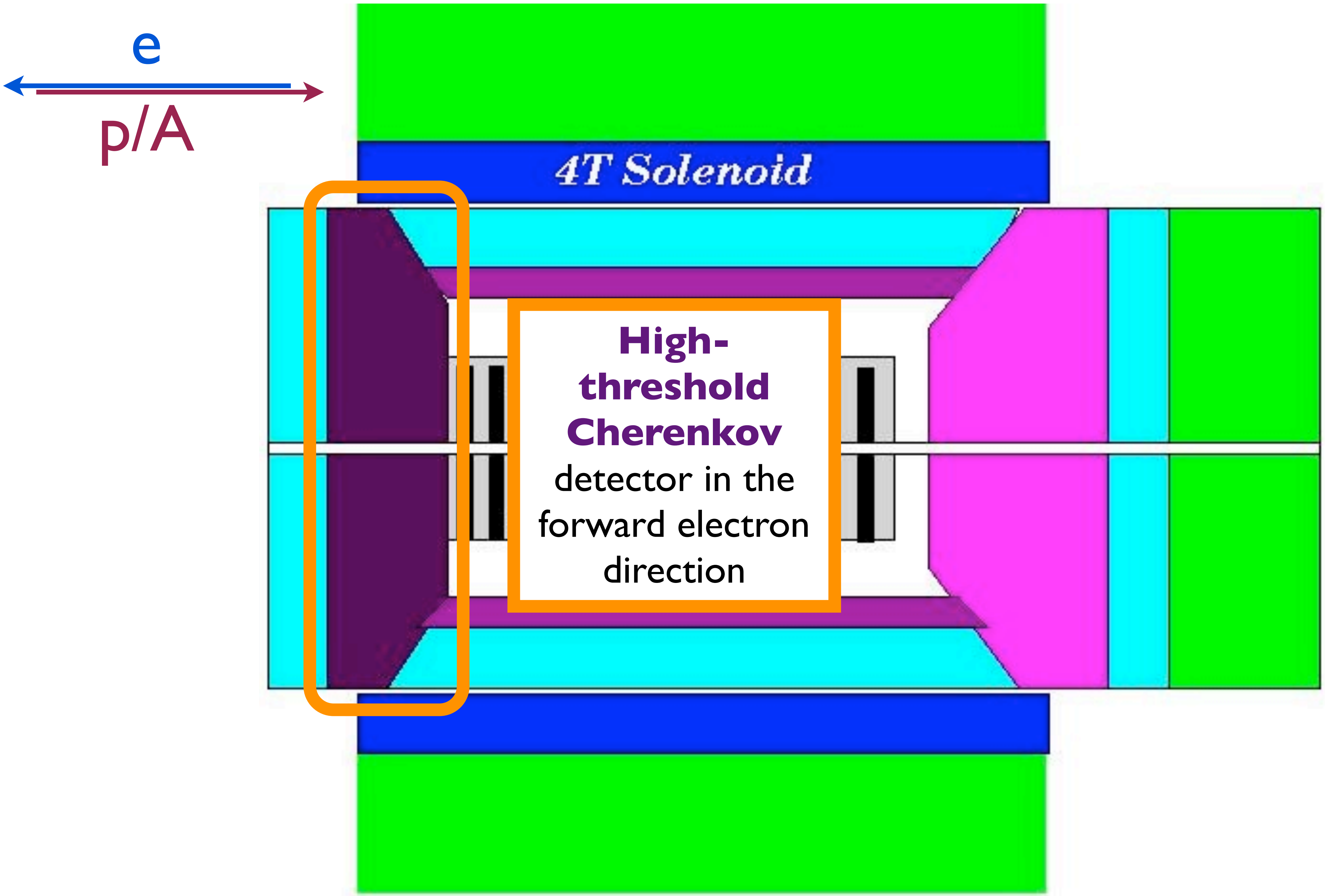
Hadronic calorimetry covers the central and hadronic forward directions

Main detector

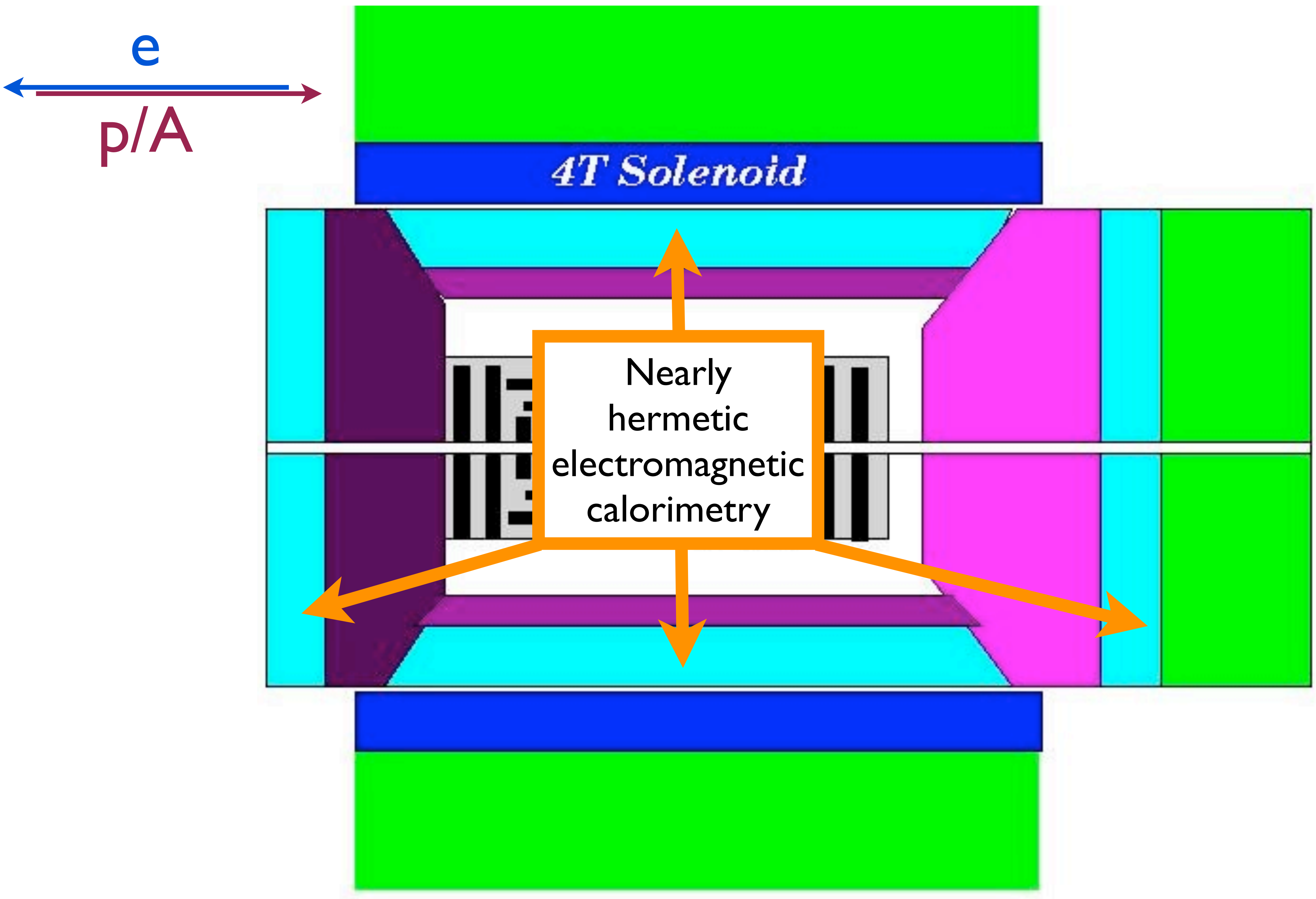


DIRC and **RICH** cover the central and hadronic forward regions

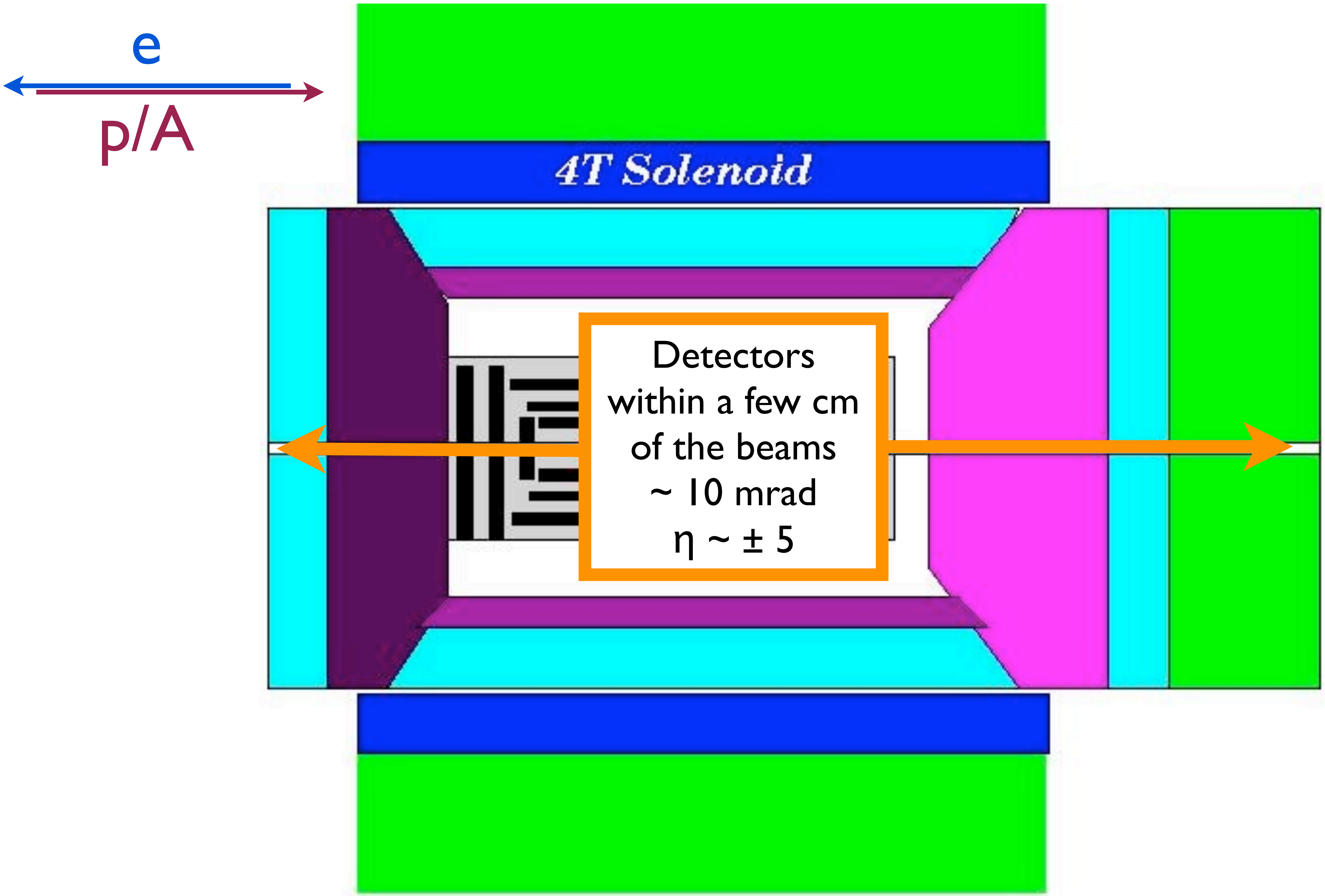
Main detector



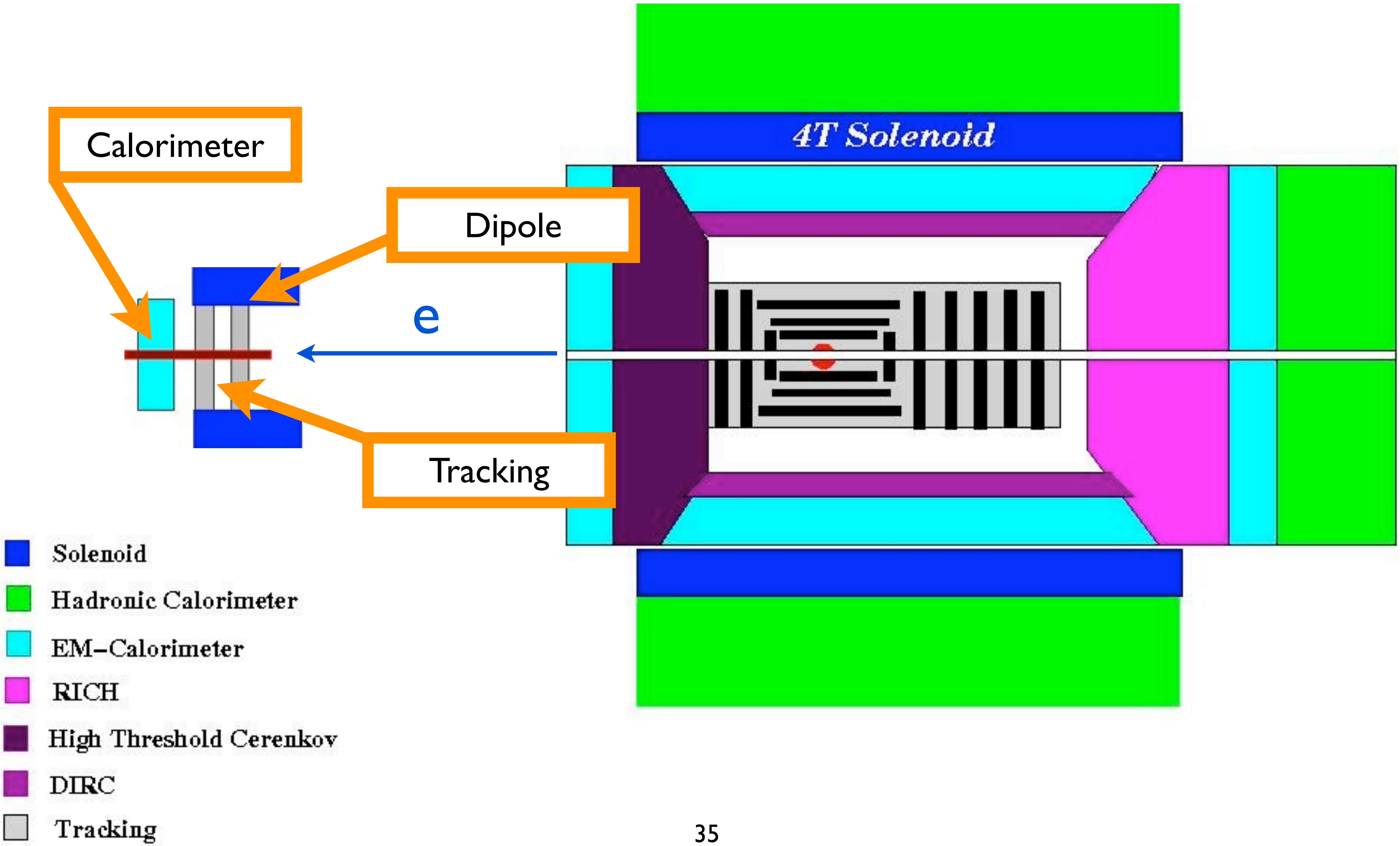
Main detector



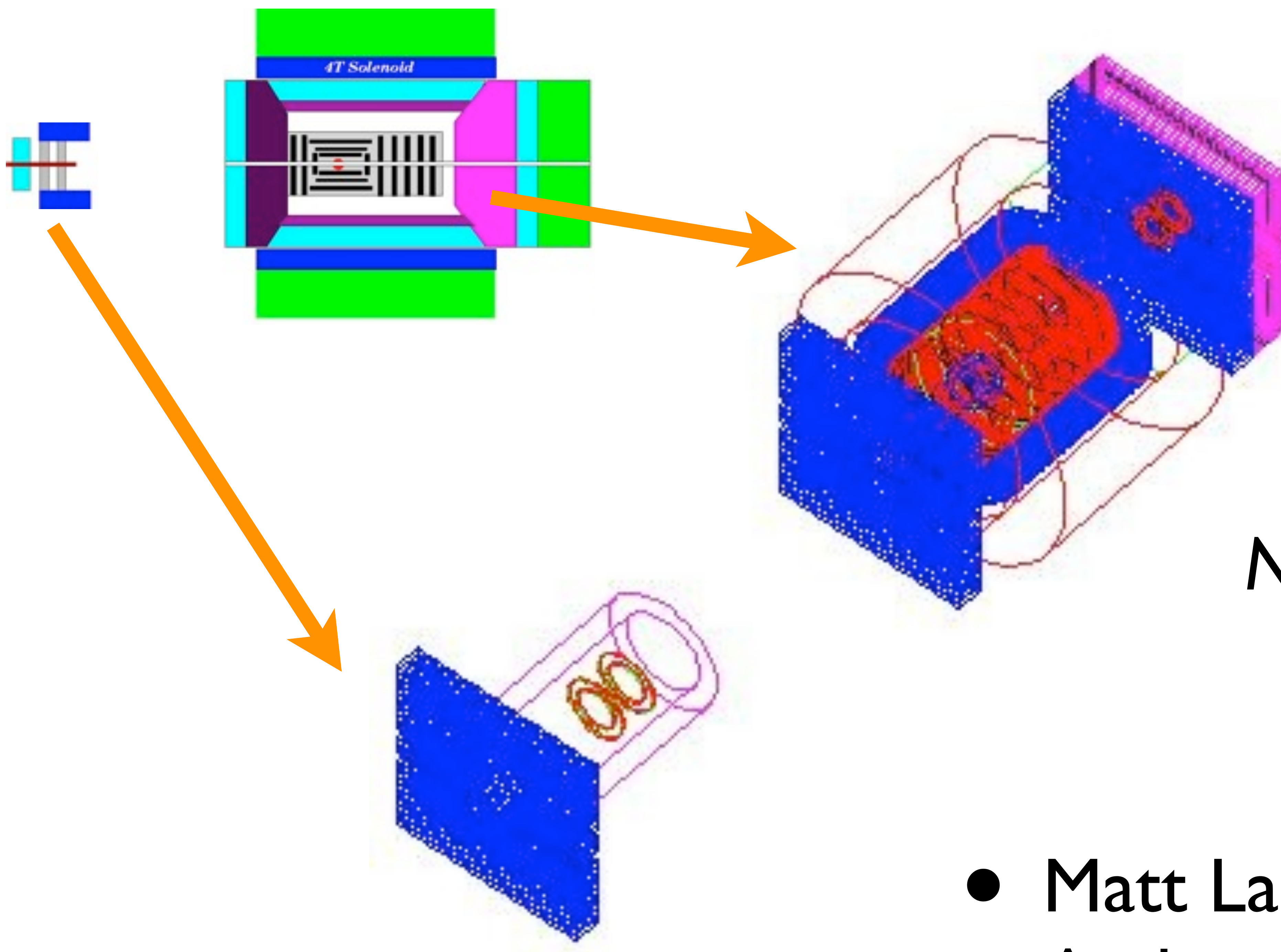
Main detector



Forward electrons



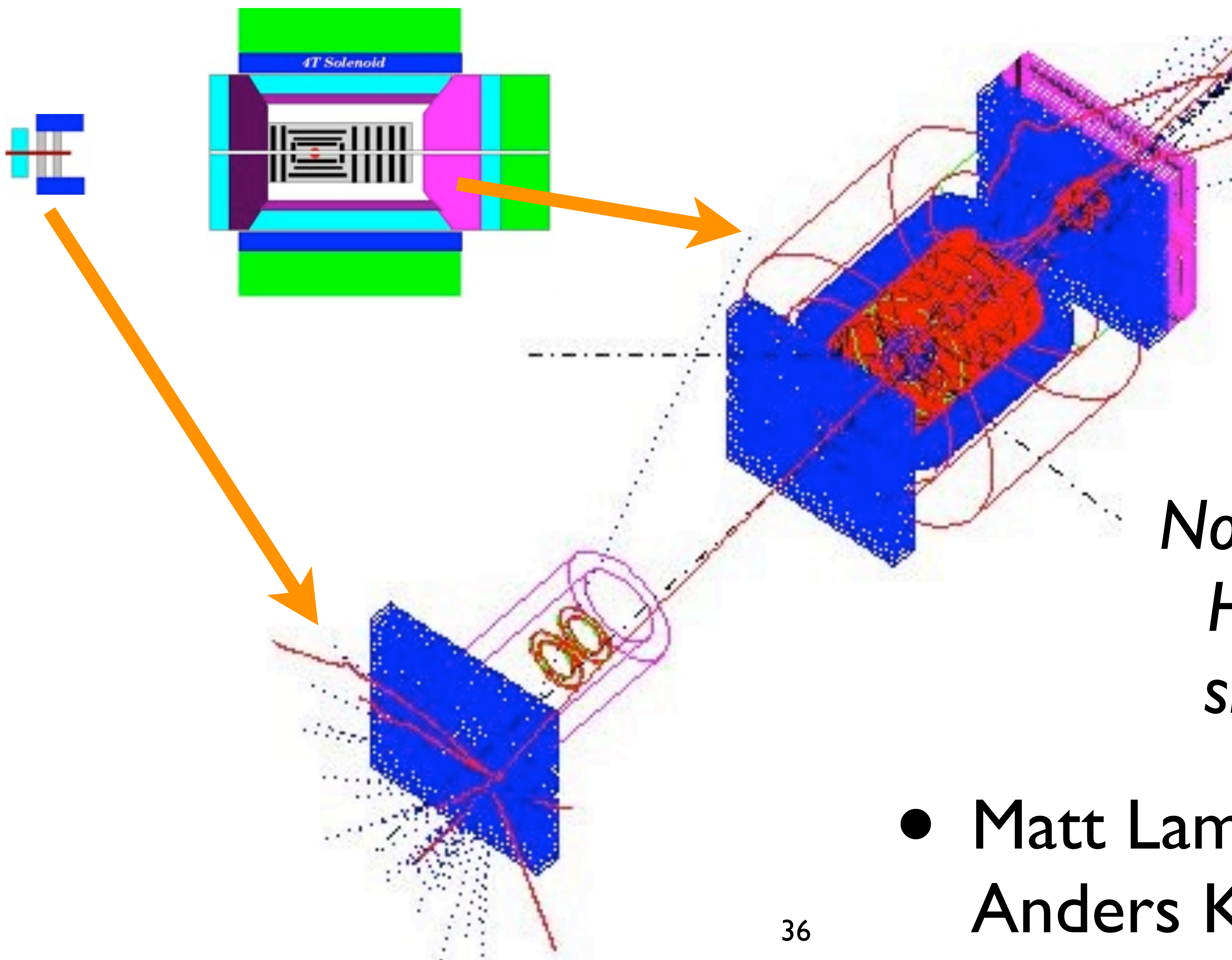
First GEANT model



No barrel HCAL shown

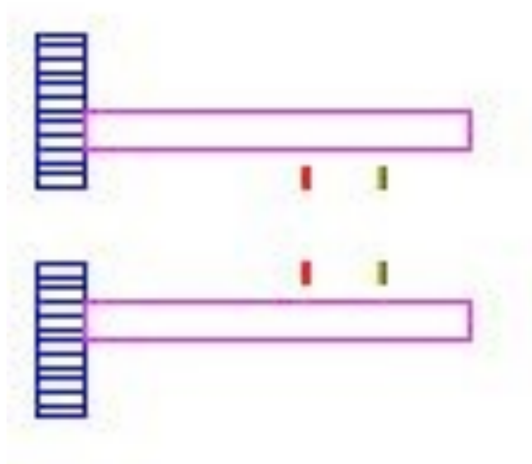
- Matt Lamont and Anders Kirleis

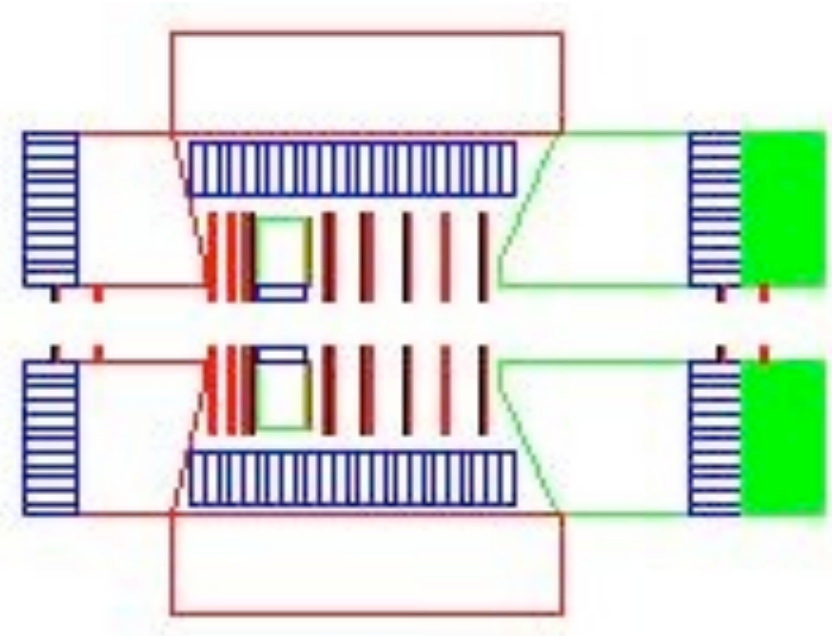
First GEANT model

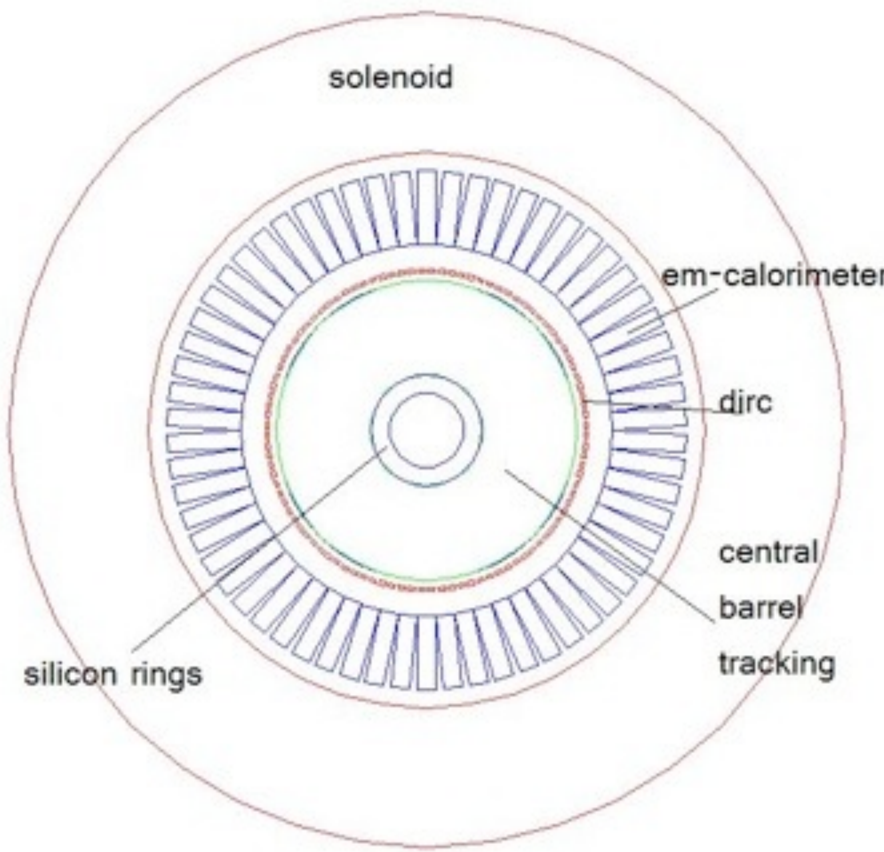


No barrel HCAL shown

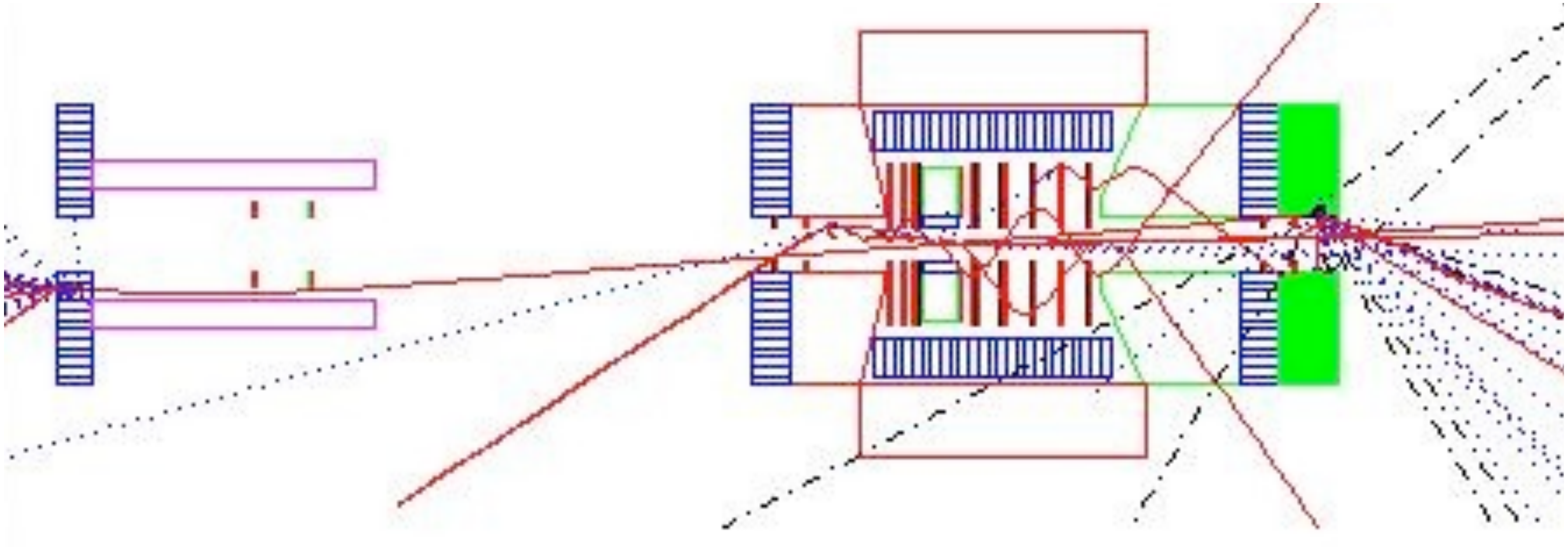
- Matt Lamont and Anders Kirleis

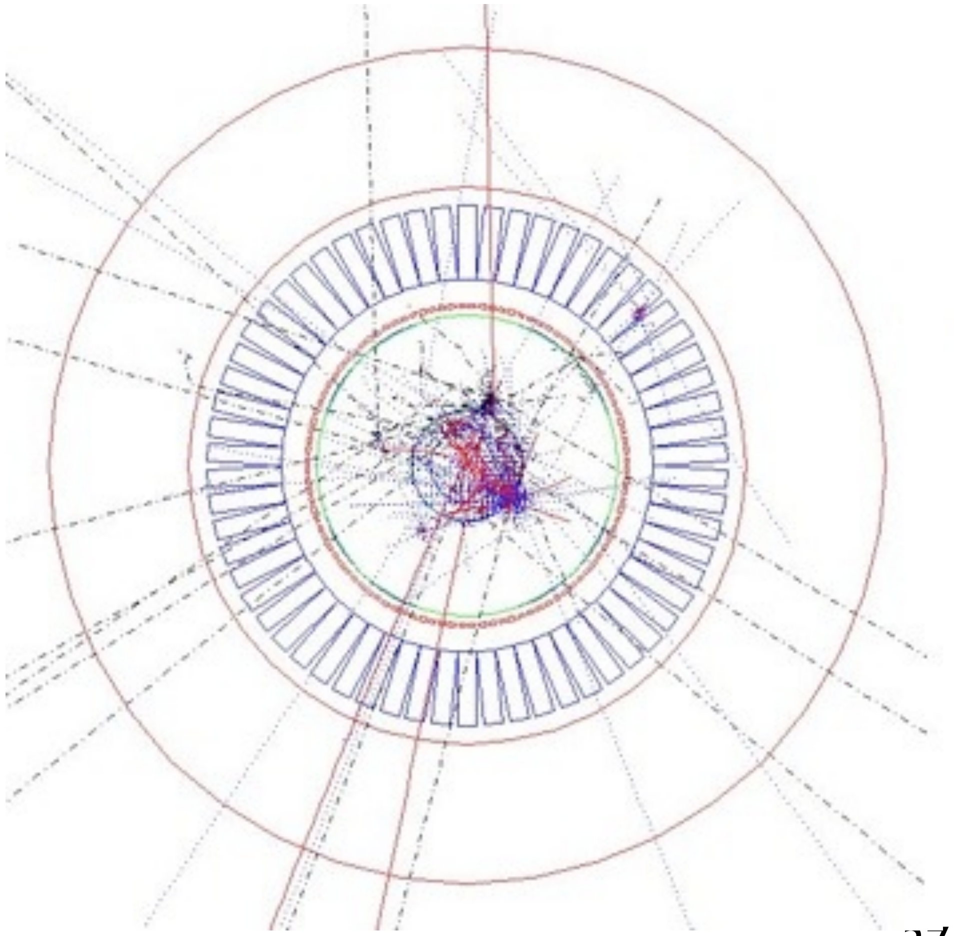






- Using Monte Carlo to test geometry, resolution.





- Using Monte Carlo to test geometry, resolution.

To do...

- Luminosity monitoring
- Polarisation measurements
- Proton detectors close to beam line
- Incorporate IR magnets into Geant
- Detailed resolution studies

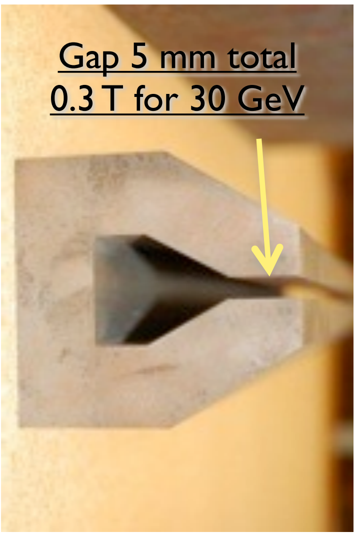
Summary

- A dedicated EIC detector must:
  - deliver a **wide physics programme**
  - **integrate** with the accelerator/IR design
- We continue to refine the design with physics & detector simulations

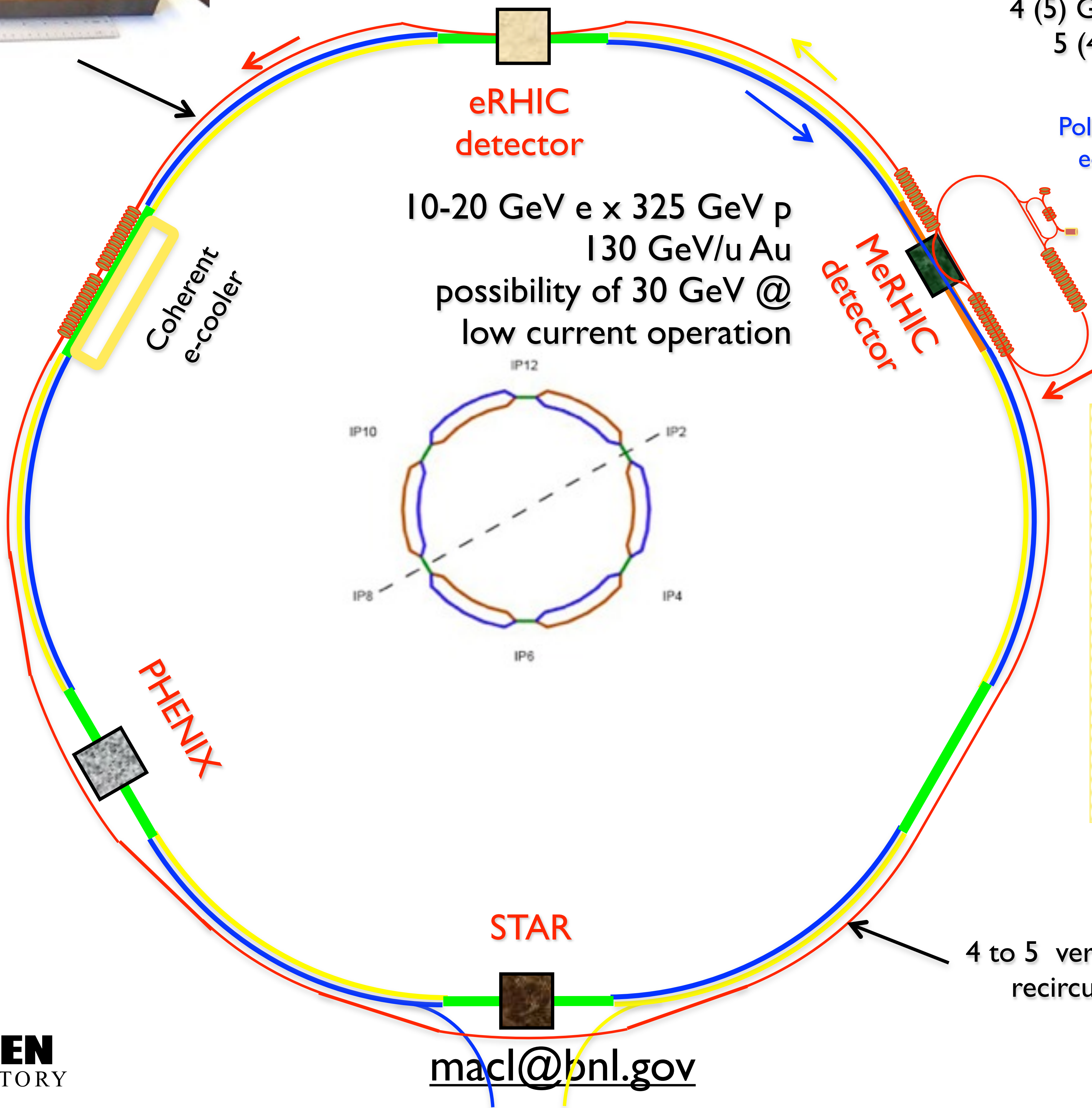
Additional material

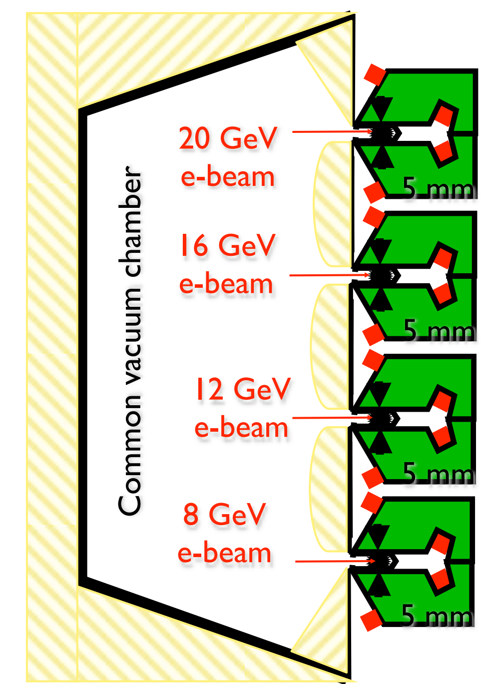
In case of questions, break glass

MeRHIC @ BNL



2 x 200 m SRF linac
4 (5) GeV per pass
5 (4) passes





4 to 5 vertically separated
recirculating passes

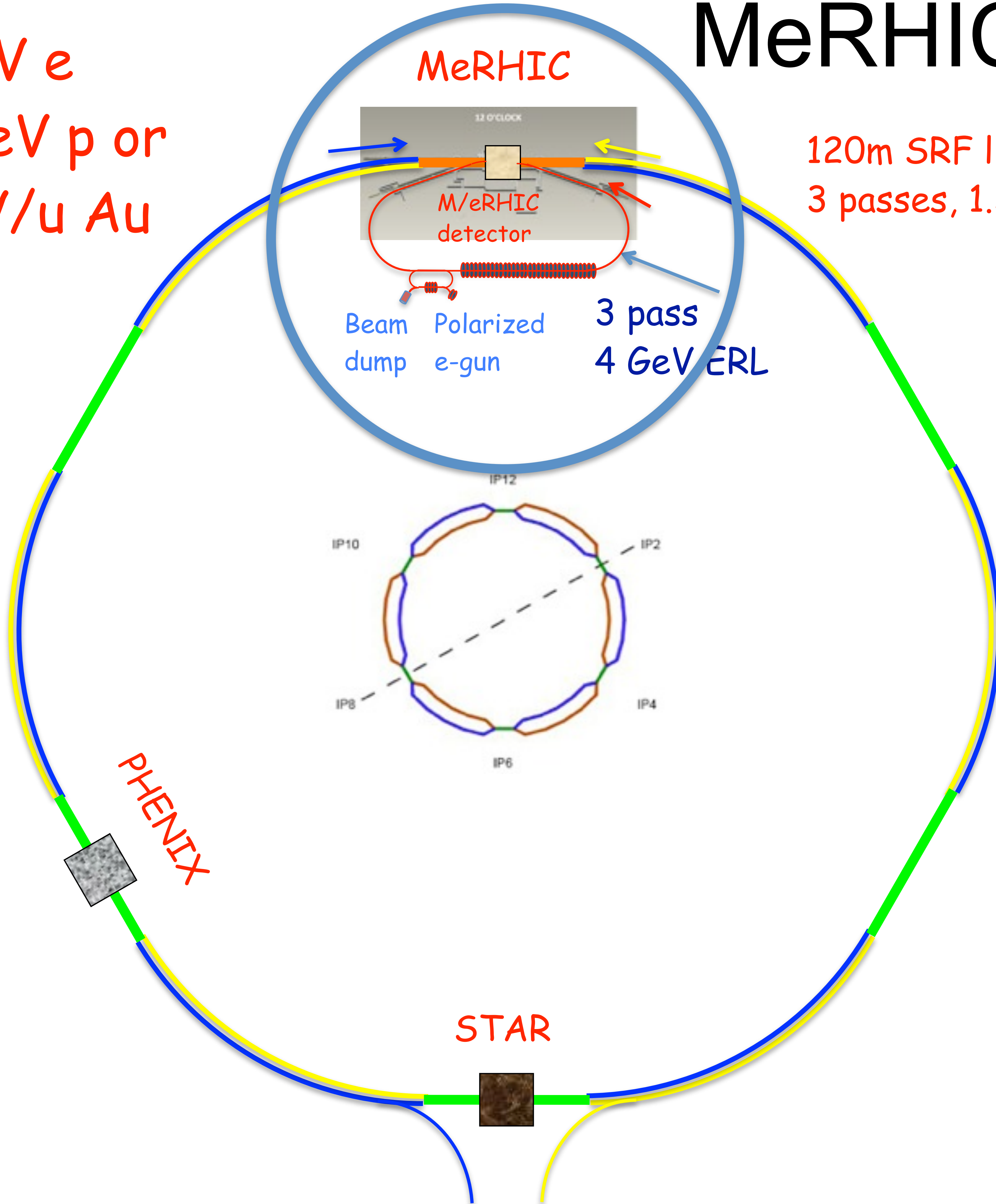
BROOKHAVEN
NATIONAL LABORATORY

macl@bnl.gov

MeRHIC at BNL

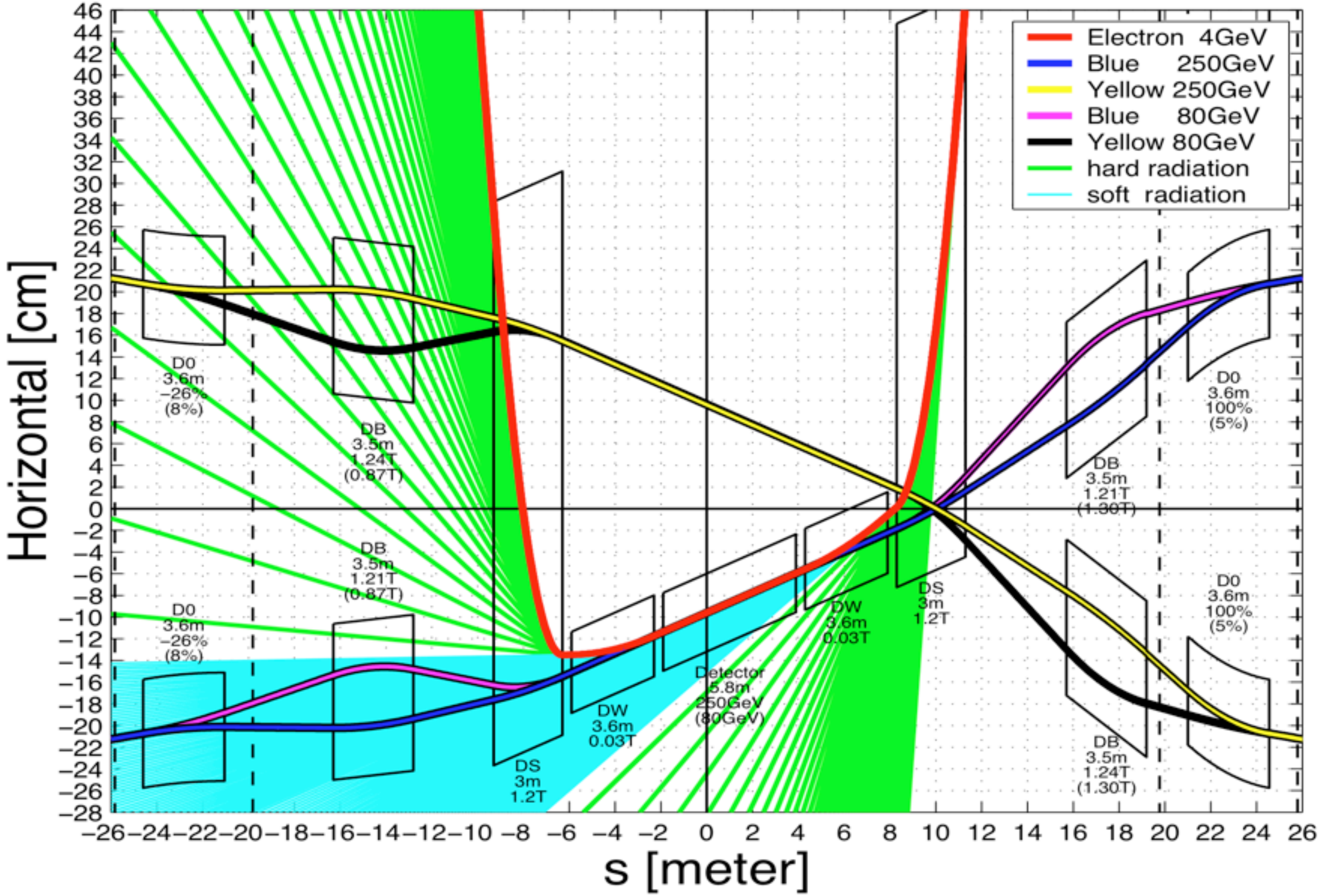
4 GeV e
x 250 GeV p or
100 GeV/u Au

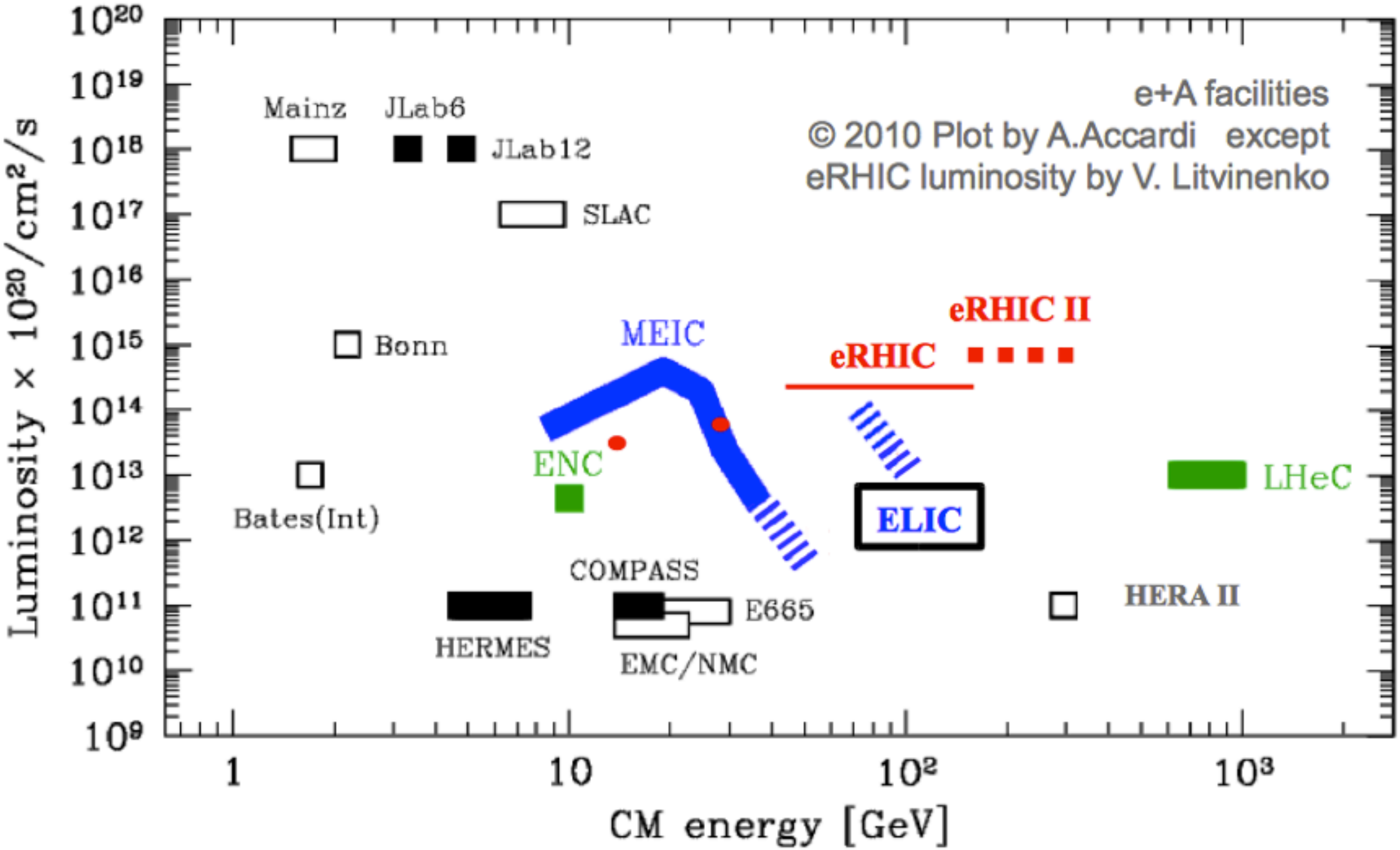
120m SRF linac
3 passes, 1.3 GeV/pass

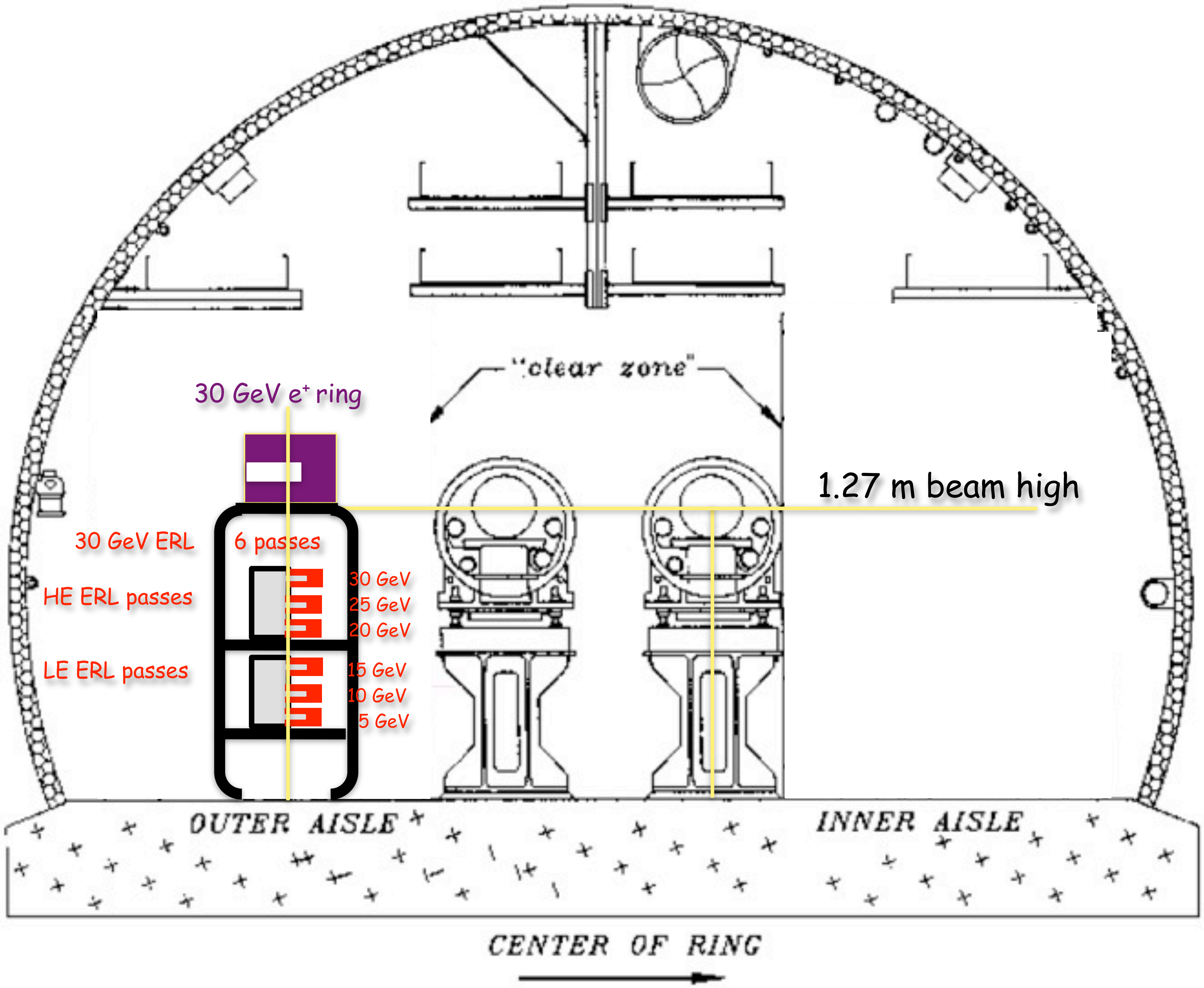


Latest IR Design for MeRHIC

- No synchrotron shielding included




e+A facilities
© 2010 Plot by A.Accardi except
eRHIC luminosity by V. Litvinenko
Luminosity × 10²⁰/cm²/s
CM energy [GeV]
Mainz
JLab6
JLab12
SLAC
Bonn
Bates(Int)
MEIC
ENC
eRHIC
eRHIC II
ELIC
LHeC
COMPASS
E665
HERMES
EMC/NMC
HERA II


30 GeV e+ ring
"clear zone"
1.27 m beam high
30 GeV ERL
6 passes
HE ERL passes
LE ERL passes
30 GeV
25 GeV
20 GeV
15 GeV
10 GeV
5 GeV
OUTER AISLE
INNER AISLE
CENTER OF RING